

Alternatives to Micro-Irrigation: Evaluation of the Treadle Pump

This paper reports the results of a survey conducted to assess the comparative performance of the treadle pump vis-à-vis other water-lifting options in villages in UP, Bihar and Orissa. The survey shows that the treadle pump is easier to operate than other types of manual irrigation systems, and that its efficiency is also greater. Its range of command area makes it especially suitable for operation on small and marginal farms. Moreover, it is more efficient than even a diesel pump.

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I Introduction

The treadle pump (TP) is a low-speed, foot-operated reciprocating pump, which originated in Bangladesh during the late 1980s. The device can be operated by standing on two bamboo levers and depressing them alternately using the feet. On average, it is able to provide a discharge of 1-2 litres per second. In India, most of the TP installations are in Uttar Pradesh, Bihar, Orissa and Assam. Generally, the bamboo versions of TPs can pump water from a depth of about 4.5m-5.75m and the metal version up to 4.5m, TPs have been adopted for application in landholdings of less than one acre.

In the early 1990s mostly the bamboo type of TPs were installed. Though the development of the metallic type of TPs by International Development Enterprises (IDE), started in the 1980s, their installation began only in the mid-1990s. The development of concrete pump is a recent one and it has been installed in the field on an experimental basis by IDE in Orissa.

Mostly, a suction pipe of diameter 2.8 cm is used for all types of TPs, similar to that used for hand pumps. Two cylinders are joined with the suction pipe using a union joint. A sketch of the bamboo and metallic TP is given in Figures 1 and 2. Plungers (pistons) which are joined to the treadle poles using bolt-nut mechanism do the reciprocatory motion in the cylinders.

All bamboo pumps developed and installed are of 8.75 cm cylinder diameter, with a maximum output of 1.5 litres per second of water lifted from a depth of 5.45-5.75m. The cost of bamboo pumps is lower than that of other types.

In case of bamboo TP, the treadle poles used for pedalling, support poles, separation poles, are all of bamboo, generally obtained locally. Cylinders and plungers are of metal and the washers of rubber. The pipe (suction) used is often made of PVC material.

Metallic pumps were developed by the IDE in two sizes 8.75 cm and 12.5 cm cylinder diameter. The 12.5 cm pumps provide an output of 1.5-2 litres per second under suitable conditions. The piston stroke is more consistent since the assembly is more rugged. The cost of the 12.5 cm metallic TP is the highest compared with other types. In case of both metallic pumps, the whole assembly of treadle poles used for pedalling, axle pivot and the cylinders come as one unit with a base plate, and is made up of metal, usually mild steel.

Concrete pumps have been recently developed by IDE in order to address the problem of incorporation of mild steel components in the metallic pumps in coastal areas. The cylinders used in this case are made of PVC. The cylinder diameter is about 12.5 cm. The output of this type of pump is comparable to that of the 12.5 cm metallic ones. The washers are made of hard plastic tubes. The supporting frame is made of concrete block, which reduces the utilisation of metallic components. The cost of this system is between that of the bamboo and metallic types.

In India, there are a large number of small and marginal farmers and the landholding is characterised by increased fragmentation. These are some of the factors that favour a device like the TP. This study was conducted in Uttar Pradesh, Bihar and Orissa, since most TPs have been installed in these states.

II Methodology

The study was carried out in three states (list of villages, districts and states are given in Annexure). The districts and villages were selected from secondary information and discussions with the local IDE officials and local NGOs. The objective of the study is to assess the comparative performance of the TP vis-à-vis other available water-lifting options in the region including diesel, for varying field conditions.

The sample selection was done for two purposes. One was to conduct the evaluation through feedback from beneficiaries and other was through actual field testing. Sample selection was through a short-listing procedure based on secondary information and suggestions from local IDE officials and NGOs. Random sampling was followed to evaluate the TPs using questionnaires, which basically involved getting a response from the users.

The sample size was 54 households in Bihar, 51 households in Uttar Pradesh and 39 households in Orissa. The questionnaire was thus administered in 144 households. This was basically for interaction with the owners to get a feedback from the beneficiaries. The sample was suitably stratified across the districts depending on the population size of TPs. Of the sample, 10 per cent was selected for detailed pump-testing and performance evaluation.

Installations of TPs have been carried out in the terai areas of Uttar Pradesh, plains around Varanasi, Bihar and areas in Orissa. In Uttar Pradesh, the bamboo version is common. In Bihar,

Figure 1: 8.75 cm Bamboo Type Treadle Pump

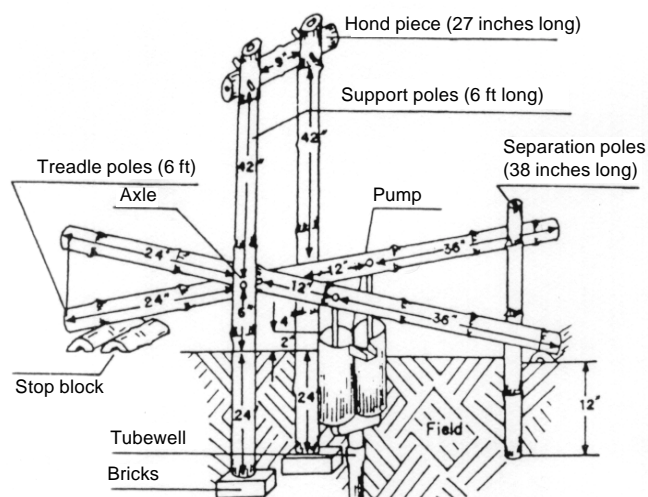
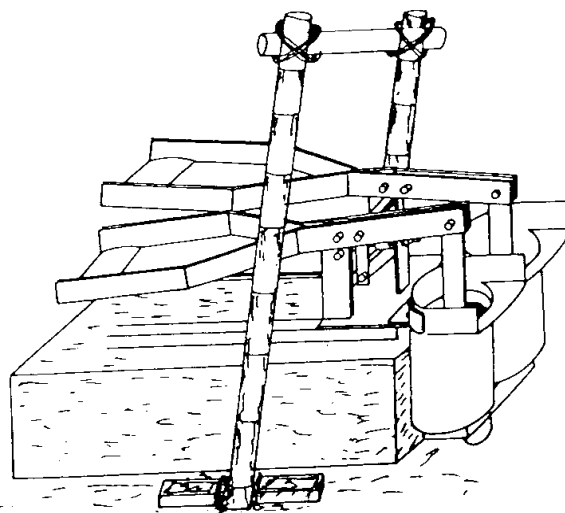


Figure 2: 12.5 cm Metallic Type Treadle Pump



metal pumps have also been installed along with the bamboo version. In Orissa, mostly metal pumps have been installed but the recently developed concrete version has also been introduced. A suitable number of pumpsets from each category were selected for evaluation.

each such stroke provides delivery. Frequency measurements were taken to determine the comparison that could be made with the discharge, tiredness and other factors.

III Results and Discussion

Field Testing of TPs and Other Water-lifting Devices

Evaluation of Treadle Pump based on User Feedback

Technical assessment of 10 per cent of the total sample size was done. The traditional device 'dhekuli' and diesel pumpset was also selected for testing. The sample was drawn from all three states.

The evaluation was based on feedback from users through structured questionnaires. A total of 144 households were covered.

The tests involved the measurement of a number of parameters, such as water discharge, volume of water pumped in a typical cycle, and effective utilisation time frequency.

A large number (56 per cent) of TP users had less than one acre of land. TPs were mainly adopted by small and marginal farmers (72 per cent). The distribution of TPs according to landholding is given in Table 1.

Estimation of energy input and of system efficiency of various water-lifting devices was calculated. Techniques of work study were applied in order to obtain an idea of the operation and fatigue on the part of the operator. Instruments used were electronic stopwatch, container (of known volume), portable weighing machine and measuring tapes:

Almost 40 per cent of the households operated the TP for 1-2 hours a day. About 42.4 per cent operated the TP for 3-4 hours a day. The details of TP operation per day in different households is given in Table 2.

The testing procedure was as follows.

In Uttar Pradesh and Bihar, the devices used for irrigation prior to the adoption of TP were diesel engine pumpsets on hire, manual water-lifting systems like dhekuli, sing basket and handpumps. In Orissa 'tenda' and 'janta' were also used. The use of tenda has been completely stopped after adoption of TP in Orissa. This implies that tenda operation is much more strenuous compared with TP operation.

(a) The user was instructed to operate the pump in a routine fashion (without getting influenced by outsiders' presence or the fact that experiments were being conducted). They were also allowed to operate in shifts if that was the procedure followed. The portable weighing machine was used to take the operator's weight, and her/his age was recorded.

Table 1: Treadle Pump Distribution According to Landholding

Category of Farmers	Percentage	Number of Farmers
Marginal farmers (< 1 acre)	56	76
Small farmers (1-2.5 acres)	16	22
Medium farmers (2.5-5 acres)	18	24
Large farmers (> 5 acres)	10	14
Total	100	136

(b) A container of known volume was used to measure discharge. An electronic stopwatch was used to note down the time required for the known volume of water collected in the container. Readings were taken at an interval of five minutes.

Table 2: Distribution of TP According to Hours of Operation

Number of Hours Per Day	Number of TPs	Percentage
1	18	13.6
2	35	26.5
3	25	18.9
4	31	23.5
>4	23	17.4
Total	132	100

(c) A typical routine operating cycle by the beneficiary was taken as the duration of the cycle for testing. This would give realistic measurements and observation.

(d) The average discharge readings were used to compute the volume of water pumped during the cycle of operation. Care was taken to use different averages to compute the total quantity of water pumped, in case of operation by two operators with two different rates of discharge.

(e) In case of TP, strokes per minute of pedalling was noted down. Single-leg movement was taken as one stroke, because,

The economy of the study area mainly depended on agriculture. Vegetables were the main cash crop for marginal and small farmers, foodgrains were grown mainly for self-consumption. Vegetables like brinjal, tomato, lady's finger, pumpkin, chillies, potatoes, onion, cabbage, bean and bitter gourd are grown with TP irrigation.

Some other observations were also made, and listed below.

- (a) About 55 per cent households operated the TP for about 100 days in a year;
- (b) About 47 per cent of the beneficiaries said they could operate the TP continuously for about half an hour without feeling much strain;
- (c) Most of the users are of the opinion that they do not feel any serious physical fatigue in operating the pump;
- (d) Women feel quite comfortable in operating the pump. Children also operate the pump but for lesser duration;
- (e) Crops grown largely are vegetables using TP device for irrigation.

Technical Evaluation of TPs

Tests were conducted on selected TPs, diesel pumpsets and also on manual the irrigation system dekhuli. The tests were conducted to determine the performance of the irrigated devices and to the relative performance, and convenience.

Technical evaluation of TPs was conducted at 12 sites. Six of these were 8.75 cm bamboo type, one 8.75 cm metallic and two 12.5 cm concrete type. The details of the test site measurements made and the results are presented below.

The details of type, size of the pump, and age are given in Table 3. The age varied from two to 36 months. However, one 8.75 cm metallic pump was 42 months only. This was based on feedback from the beneficiary. As far as the age of the pump is concerned, we had to depend on responses from the beneficiary, mason or the implementing agency. However, the concrete pump is a recent development and installed in the field only a few months back.

The details of the operator give some indications to assess their healthfulness. As seen from Table 3, men operate the pumps most of the time and only in a few cases do women and children operate it. Women and children mostly help in other activities in the field when the man is operating the treadle pump. The age of the operators varied from nine to 50 years. Most were in the age group of 30 to 40. Weight of the operator was mostly 45 to 50 kg.

Measurements were also made to determine the discharge and frequency of pedalling. Table 4 also provides the depth of water table at the test sites, which was procured from the masons who installed the pumps and users, and cross-checked with NGOs where possible.

Total testing time is given in the table for each site. Typical operating time by the user was taken as the testing duration. However, the duration of operation in many cases was less than the normal operation since the tests were conducted during the peak summer season. However, in Orissa, the situation was the reverse because of unexpected heavy rains and floods, and there were some problems in testing. We had requested a few users to operate the pump for testing, though they did not want to water their land because of the rains. The maximum duration for testing was about 115 minutes in Orissa and the minimum was 20 minutes in Uttar Pradesh. Average duration for the experiments was about 61 minutes.

The discharge measurements were taken once every five minutes in most of the experiments. The maximum average discharge was 89 lpm for a 5" metallic type (at a depth of 10 feet) in Orissa and minimum average discharge was 33 lpm for a 3.5" bamboo type (at a depth of 20 ft) in Bihar. However, there was one pump which gave an average discharge of 10 lpm, was operated by children and in a very bad condition. In addition, the operation was also faulty, in the sense that the operator was not using the full stroke. One of the reasons could be leakage in the suction pipe. Such a low discharge rate was not observed anywhere else while testing as well as based on the feedback.

The frequency of pedalling was also measured once in five minutes during the test period. Each stroke was taken as one unit of operation and counted as one. This would mean output from one cylinder. The maximum average frequency was about 133 for a 12.5 cm metallic unit and the minimum was 39 for 8.75 cm bamboo type. However, it could be implied that when the average frequency was 90 or more, the average discharge was also higher. However, establishing a relation between frequency of pedalling and discharge is very difficult. In many cases it was observed that when the operator is tired, higher frequency was observed with the same discharge rate or some times even lesser discharge rates.

Energy input, output and systems efficiency have been calculated for a few sites covering all types of TPs. The efficiencies

Table 3: Details of TP Test Sites in Study Area

State	Type of Cylinder	Dia of Cylinder (Inch)	Age of Pump (Months)	Sex (M/W/C)	Weight (Kg)	Age of Operator (Year)
Uttar Pradesh	Bamboo	8.75	10	MW	49.5 and 36	36 and 30
Uttar Pradesh	Bamboo	8.75	2	MW	52.5 and 41	35 and 32
Uttar Pradesh	Bamboo	8.75	42	M	49	17
Uttar Pradesh	Metallic	12.5	18	MC	49.5 and 38	50 and 12
Bihar	Bamboo	8.75	36	M	39.5	35
Bihar	Bamboo	8.75	12	M	48	38
Bihar	Bamboo	8.75	12	MC	45 and 39	18 and 13
Bihar	Metallic	12.5	8	MC	45 and 47	26 and 17
Bihar	Metallic	8.75	24	MC	27 and 21	13 and 9
Orissa	Concrete	12.5	3	M	55	32
Orissa	Metallic	12.5	12	M	50	46
Orissa	Concrete	12.5	6	M	50	34

Notes: M - Male, W-Woman, C-Children. Sex, weight and the age given are in the same order.

Table 4: Measurement Details of TP Testing

District	Dia of Cylinder (cm)	Type of TP	Age of Pump (Month)	Water Table (Metres)	Total Time (min)	Avg Discharge of Water (lpm)	Frequency of Pedalling (Stroke/min)
<i>Uttar Pradesh</i>							
Gorakhpur	8.75	Bamboo	10	4.54	80	56	90
Gorakhpur	8.75	Bamboo	2	6	70	52	97
Gorakhpur	8.75	Bamboo	42	6	25	33	122
Gorakhpur	12.5	Metallic	18	4.54	20	68	90
<i>Bihar</i>							
Muzaffarpur West	8.75	Bamboo	36	6	30	29	50
Champaran West	8.75	Bamboo	12	5.45	40	46	39
Champaran West	8.75	Bamboo	12	5.45	85	53	46
Muzaffarpur	8.75	Metallic	24	6	105	35	44
Muzaffarpur	12.5	Metallic	8	4.8	25	10 ^a	63
<i>Orissa</i>							
Balasore	12.5	Concrete	3	4.54	65	79	127
Balasore	12.5	Metallic	12	6	115	89	133 ^b
Balasore	12.5	Concrete	6	3.63	70	74	118

Notes: a: Children operators were physically weak and unaware of proper operation of pump.

b: The person was quite healthy and operated with proper attention.

range from 39 per cent to 52 per cent. Specimen calculation for one TP has been presented in detail. The system efficiency depends on various parameters such as weight of operator, strokes per minute, head (water table), discharge and stroke length. The energy input and output in Joules per minute have been calculated and are presented in Table 5.

The specimen calculations for a treadle pump for one of the test sites are given in Table 6.

Efficiency for Mahangu Nishad's TP is as estimated below

$$\text{Efficiency} = (E_{\text{output}}/E_{\text{input}}) \times 100, \text{ where}$$

$$E_{\text{input}} = \text{Mass of operator} \times \text{acceleration due to gravity} \times \text{strokes/min} \times \text{stroke length}$$

$$E_{\text{output}} = \text{Discharge of water} \times \text{acceleration due to gravity} \times \text{total head}$$

$$E_{\text{input}} = 49.5 \text{ (kg)} \times 9.8 \text{ (m/sec}^2\text{)} \times 87 \text{ (strokes/min)} \times .145 \text{ (metre)}$$

$$= 6119.54 \text{ joules/min}$$

$$E_{\text{output}} = 57 \text{ (lpm)} \times 9.8 \text{ (m/sec}^2\text{)} \times 4.5 \text{ (metres)}$$

$$= 2513.70 \text{ joules/min}$$

$$\text{Efficiency} = 2513.70 \text{ joules/min} \div 6119.54 \text{ joules/min}$$

$$= 41 \text{ per cent}$$

Performance of Dhekuli: The performance of the traditional manual water lifting system, dhekuli, has been calculated and the details are given in Table 7. A similar method to that of TP has been used to determine the system efficiency of the dhekuli. The system efficiency of dhekuli comes to about 6.35 per cent.

Performance of diesel pumpsets: Discharge was measured using a 180 litres capacity drum and total head was taken as 30 feet (18 feet is the static head and 12 feet is assumed as friction losses occurring in strainer, suction discharge pipe, pump and fittings). The rpm of diesel pump was measured by tachometer and time measurement was done using an electronic stop-watch. The details of the instruments used for measuring the various parameters are given in Table 8.

The performance of two diesel pumpsets along with calculations are given in Table 9.

Here, Efficiency = $(E_{\text{output}}/E_{\text{input}}) \times 100$, E_{input} = Energy input = diesel consumption (lit/hr) \times specific gravity \times calorific value; Specific gravity = 0.831; Calorific value of diesel = 10,000 kcal/kg = 41,800 kJ/kg; E_{output} = energy output = $\rho(\text{water}) \times \text{flow rate} \times g \times \text{head}$; $\rho(\text{water})$ = density of water = 1000 kg/m³; g = acceleration due to gravity = 9.8 m/sec²; Q = Flow rate (m³/hr); H = Total head (m).

Calculations: Efficiency for Prabhat Das's diesel pumpset is estimated as:

$$E_{\text{output}} = (1000 \times 9.8 \times 1.805/460) \times (30 \times 12 \times 2.54/100) \times 3600$$

$$E_{\text{input}} = (1 \times 0.831 \times 10000 \times 4.186 \times 1000)$$

Comments: These experiments were conducted on a rainy day. Both pumps were quite old. The farmers were using them for irrigation in their land and as well as for hiring purposes.

Table 5: Test Results (Energy Input and Output and System Efficiency) of TP

Site	District	Capacity and Type of Pump (cm)	Discharge (lpm)	Weight of Operator (kg)	Water Table (m/sec ²)	Frequency (spm)	Stroke Length (m)	Net Operated Time (min)	Energy Input (Joules/min)	Energy Output (Joules/min)	Efficiency (Per Cent)
IX	Gorakhpur	8.75, B	57	49.5	4.5	87	0.145	45	6120	2514	41
IY	Gorakhpur	8.75, B	55	36	4.5	93	0.145	35	4758	2426	51
2X	Gorakhpur	8.75, B	55	52.5	6	97	0.125	45	6238	3234	52
9	Muzaffarpur	8.75, M	10	27	6	63	0.089	25	1482	588	40
10	Balasore	12.5, C	79	55	4.5	127	0.127	65	8683	3470	40
11	Balasore	12.5, M	89	50	3	133	0.089	115	5794	2617	45
12	Balasore	12.5, C	74	50	3.6	118	0.114	70	6609	2611	39

Notes: X – Treadle Pump operator number first, Y – Treadle Pump operator number second, B – Bamboo, M – Metallic, C – Concrete Net operated time : Total time operated by one person during the testing.

Prabhat Das's pumpset was in a better condition and properly coupled. About Rs 1,000 per year is being spent on maintenance after three years of installation.

Table 6: Experimental Details for Mahangu Nishad's Site (8.75 Bamboo Type)

Experimental Details	3.5" Bamboo TP
Name of owner/operator	Mahangu Nishad
Age (Yr)	28
Weight (kg)	49.5
Location	Karmaha, Gorakhpur, UP
Pump details	3.5"
Age of pump (yr)	0.8
Total head (ft)	15
Flow (lit/sec)	0.95
Fuel consumption (lit/hr)	NA
Energy input (Joules/min)	6120
Energy output (Joules/min)	2514
Efficiency (per cent)	41

Note: NA - Not applicable.

Table 7: Performance of Dhekuli

Experimental Detail	Performance Device
Name of operator	Shri Gabbu
Age of operator (years)	20
Weight of operator (kg)	49
Location of experimental site	Vill-Bichhawapur, Dist-Gorakhpur, UP
Used device	Dhekuli
Age of device (years)	6
Duration of experiment (min)	10
Total head (feet)	7.83
Energy output (kJ/hr)	1960 ^a

Note: ^a Human energy output Adult = 1.96 MJ-hr.

Table 8: Instruments Used for Measuring Parameters

Parameter	Instrument
Total head	Information provided by owners/mechanic
Measuring irrigated land	Measuring tape
Discharge	180 litres drum
Time	Electronic stop-watch
rpm measurement	TM-2011 Tachometer

Table 9: Performance of Diesel Pumpsets in Orissa

Prabhat Das	Paghal Malik
Village - Bamatiya, dist - Balasore	Village - Bedpur-Bati, dist-Balasore
Land owned - 6 acres	Land owned - 7 acres
Diesel engine - 5 HP	Diesel engine - 5 HP
Pump (impeller) - 3 HP	Pump (impeller) - 3 HP
Manufacturer of pump - Kirlosker Brothers	Manufacturer of pump - Kirloskar Brothers
Age of pump - 7 years	Age of pump - 5 years
Total Head = 30 feet = 9.14 m	Total Head = 30 feet = 9.14 m
Flow rate (Q) = 3.924 litre/sec	Flow rate (Q) = 7.083 litre/sec
Diesel consumption = 1.00 litre/hr	Diesel consumption = 2.10 litre/hr
$E_{\text{input}} = 34786 \text{ kJ/hr}$	$E_{\text{input}} = 73050 \text{ kJ/hr}$
$E_{\text{output}} = 1266 \text{ kJ/hr}$	$E_{\text{output}} = 2287 \text{ kJ/hr}$
Efficiency = 3.64 per cent	Efficiency = 3.13 per cent

In Paghmal Malik's pumpset, the assembly of foundation of the pumpset was improper and hence was wobbling. Leakage of diesel from plunger of engine during operation was observed. Diesel consumption of engine was higher than normal.

Comparison of Performance of Diesel Pumpset and TPs

The performance of various types of water-lifting systems has been calculated and is presented in Tables 10 and 11. The performance of concrete pump was found out to be the highest of all the systems, at about 10.8 per cent. The efficiency of diesel pumpset is the lowest, at about 3.64 per cent.

Thus, it can be clearly inferred that the system efficiency of a TP is much higher than that of a diesel pump in comparable field situations.

Conclusions

It was observed that usually all members of a family operate the pump. However, the head of the family operates it more. Women generally operate only on a stop-gap basis. However, in a few cases, labour is being hired to operate the pump. The wages of hired labour varied from Rs 15 to 25 per day. It was felt that TP operation is much easier than other types of manual irrigation systems in the study area. On average, a TP is operated for about 100 days in a year. More than 60 per cent of the households owning TP have been using it for more than or equal to three hours on an operating day.

It was found that the discharge from all types of TPs is higher than other manual irrigation systems like the swing basket, tenda

Table 10: Comparison of Performance of Diesel Pumpset, Bamboo and Metallic TP 3.5"

Experimental Details	Diesel Pumpset (5 HP)	Treadle Pump	
		3.5" Bamboo	3.5" Metallic
Name of owner/operator	Prabhat Das	Mahangu Nishad	Bachchan Prasad Yadav
Age (yr)	NA	28	13
Weight (kg)	NA	49.5	27
Location	Bedpur-bati, Dist Balasore, Orissa	Karmaha, Dist Gorakhpur, UP	Badi-Kuthia, Dist Muzaffarpur, Bihar
Pump details	5HP	3.5"	3.5"
Age of pump (yr)	5	0.8	2
Total head (ft)	30	15	20
Flow (lit/sec)	3.93	0.95	0.18
Fuel consumption (lit/hr)	1.00	NA	NA
E _{input} (J/min)	579767	6120	1458
E _{output} (J/min)	21100	2514	635
Efficiency (per cent)	3.64	41.0	43.5

Table 11: Comparison of Performance of Diesel Pumpset and TPs-5" (Concrete and Metallic)

Experimental Details	Diesel Pumpset (5 HP)	Treadle Pump	
		5" Concrete	5" Metallic
Name of owner/operator	Prabhat Das	Gopond Das	Keshav Malik
Age (yr)	NA	34	46
Weight (kg)	NA	50	50
Location (Orissa)	Bedpur-bati, Dist Balasore	Radha Mohanpur, Dist Balasore	Taran Pada, Dist Balasore
Pump details	5 HP	5"	5"
Age of pumps (yr)	5	0.5	1
Total head (ft)	30	18	10
Flow (lit/sec)	3.93	1.23	1.48
Fuel consumption (lit/hr)	1.00	NA	NA
E _{input} (J/min)	579767	6609	5794
E _{output} (J/min)	21100	2611	2617
Efficiency (per cent)	3.64	39.5	45.0

Notes: Human energy output Adult = 1.96 MJ-hr, NA = Not Applicable.

Annexure: Location of Treadle Pumps Covered under Study

Name of Village	Name of Block	Name of District
Uttar Pradesh		
Karmaha, tola Bijauwapur	Chirgana	Gorakhpur
Amar Pasitola	Vikasnagar	Gorakhpur
Mohammadpur	Vikasnagar	Gorakhpur
Kushwaha Bichhawapur	Vikasnagar	Gorakhpur
Suku tola	Vikasnagar	Gorakhpur
Narayanpur	Vikasnagar	Deoria
Peepra Beghal	Fazilnagar	Deoria
Rasu Sommalipatti	Fazilnagar	Deoria
Moharu, Tola Kanak Peepra	Fazilnagar	Deoria
Mir Vihar	Fazilnagar	Deoria
Daulatpur	Amwa	Deoria
Pasitola	Amwa	Deoria
Dhaulpara	Mehndawal	Basti
Uttar Patti	Mehndawal	Basti
Mehndawal	Mehndawal	Basti
Vilasapur	Tangia	Maharaj Ganj
Bihar		
Mushahari	Mushahari	Muzaffarpur
Badi Kothia	Mushahari	Muzaffarpur
Maujma	Paroo	Muzaffarpur
Moja Hata	Paroo	Muzaffarpur
Budimanpur	Paroo	Muzaffarpur
Budimanpur	Paroo	Muzaffarpur
Chhoti Kothia	Mushahari	Muzaffarpur
Raghunathpur	Mushahari	Muzaffarpur
Alabaga	Mushahari	Muzaffarpur
Ruknadeipur	Mushahari	Muzaffarpur
Pursottampur	Mushahari	Muzaffarpur
Dharmakta	Bagaha	West Champaran
Gobraura	Lauria	West Champaran
Sauraha	Lauria	West Champaran
Orissa		
Taran Pada	Simariya	Balasore
Bati	Mushahari	Balasore
Brinchipur	Simariya	Balasore
Khirkana	Balasore	Balasore
Radhamohanpur	Simariya	Balasore
Shyam Sunderpur	Simariya	Balasore
Pursottampur	Simariya	Muzaffarpur
Jamujhadi	Simariya	Balasore
Bamatiya	Balikhana	Balasore
Jalanga	Bhadrak	Bhadrak
Olang	Bhadrak	Bhadrak
Kursing	Bhadrak	Bhadrak
Daisingha	Bhadrak	Bhadrak
Chadhia	Bhadrak	Bhadrak
Padhanipur	Basudoabpur	Bhadrak

and dhekali, which are common in the study area. On average, well maintained TPs give an discharge of about 50 to 90 litres per minute at a depth of about 4.54 m. The highest noted for a bamboo type was 56 litres per minute at a depth of 4.54 m, 89 litres per minute for a metallic pump at a depth of 3 m and 79 litres per minute for a concrete pump at a depth of about 5.54 m.

TPs were found to be effective to operate a command area of about one acre. It is most suited for marginal and small farmers. The design of the TP is more improved and convenient to operate in comparison with other type of devices using human power. A comparison of system efficiencies indicates that it is much more efficient than a diesel pump. It also scores over other manual irrigation devices with much higher system efficiencies. The study results show that the system efficiency for a diesel engine in the comparable field situation has been only 3.64 per cent, whereas for TPs it was over 40 per cent. The system efficiency of dhekali was over 6 per cent, however, dhekali generally cannot be operated for longer duration because the operator gets too tired and the water table in the well goes down. Among the other devices, the swing basket can only lift water from surfaces such as channels. In addition, it requires two persons to operate. Tenda, common in Orissa, can lift water from the surface and the operation is also strenuous. [17]

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