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Techno economic feasibility of manual low lift pumps for irrigation in shallow water table areas of Brahmaputra valley of Assam

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ABSTRACT : A single cylinder manual hand pump of cylinder size 300mm x 225 mm fabricated at Assam Agricultural University, Jorhat and a double cylinder commercial pedal pump of cylinder size 300 mm x 88.9 mm was tested at laboratorities at Assam Agricultural University, Jorhat, Assam and at farmer's field in 5 districts of Brahmaputra valley of Assam during 2011-13 for their techno economic feasibility for irrigation. Discharge head relationships on the basis of pumping test for both the pumps were established. Discharge variation in high head was found to be prominent in manual hand pump for single person operation. Pedal operated pump though producing less discharge , was found to be better preferred by farmers' because of ease of operation , water lifting capability in terms of head and field security. Discharge and power requirement estimated from equations developed also established superiority of pedal pump. This pump was further subjected to farmer's participatory action research in 5 districts of Brahmaputra valley of Assam . Total 21 units were tested for irrigating different crops of farmer's choice. Cultivation of tuberose in Nalbari district , Ridge gourd and cabbage in Sonitpur district recorded highest benefit cost ratio (8.50), highest increase in yield over farmer's practice (78.8 %) and highest field water use efficiency (3557.69), respectively.

KEY WORDS : Manual hand pump, Pedal pump, Head –discharge relation, Power requirement

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Assam is located between latitudes 24°08'N & 27°59'N and longitudes (89°42'E & 96°01 'E, is the most populous State in the North-East India. The Brahmaputra flows from east to west for about 700 km within Assam and has great role in the ground and surface water availability. The annual replenish able groundwater resource and net annual groundwater availability of Assam is 30.35 billion cubic meter and 27.81 billion cubic meter, respectively. The annual groundwater draft is estimated as 6.026 billion cubic meter of which 5.333 billion cubic meter is for irrigation and 0.69 billion cubic meter is for domestic and industrial uses. The overall stage of groundwater development in the State is 22% and has been categorized as 'safe' (GOI , 2012) . Ground water may be a good source of irrigation water for Assam. State agriculture department has been encouraging shallow tube well irrigation coupled with 5 hp CI engine pump set. But such pumps are not very attractive for small and marginal farmers which occupy 85.3% holding in Assam. Rising fuel prices has also made these pumps unsustainable. Traditional manual water lifting devices are the only option available to the farmers. There is scope for use of improved manual pumps for irrigation in shallow water table area. Pedal operated pump technology, has already been proved to be useful in many such shallow water table areas in India and Bangladesh (Rao, 1996, Shah *et al.*, 2000). Although Assam has large areas under shallow water table with predominantly small and marginal farmer, no concerted effort has been made so far on techno economic feasibility of manual low lift pump for irrigation on laboratory or field level. Through the present study, an effort was made to evaluate techno economic feasibility of manual low lift pump for shallow water table areas of Brahmaputra valley of Assam.

METHODOLOGY

The study on manual low lift pump was conducted during 2011-13. Two pumps as described in Table A were first tested at Assam Agricultural University, Jorhat. Pump-1 was a fabricated at Department of Agricultural Engineering, Assam Agricultural University, Jorhat with cylinder diameter 22.5

cm (made of 4.0 mm thick MS sheet). The piston consisted of leather washer fixed in between a MS disc at the top and an aluminum alloy disc at the bottom. The piston valve and the suction valve were of flap type designs and their diameters were 21.4 cm and 10.7 cm, respectively. A handle made from 2.5 cm diameter and 116.0 cm length steel rod was provided at the two ends to facilitate single or two person operation. Pump-2 was a pedal operated commercial pump of KB (Kishan Bandhu) brand (IDEI, 2013). Before testing of the pumps theoretical equations for estimating the power requirement were established. Fig. A. shows the schematic diagram of a typical manual pump. With reference to Fig. A , when the bucket goes up the piston valve remains closed. It is the suction cum delivery stroke and during this stroke water is drawn into the cylinder through the non return valve and simultaneously water above the piston bucket is forced out through the delivery pipe.

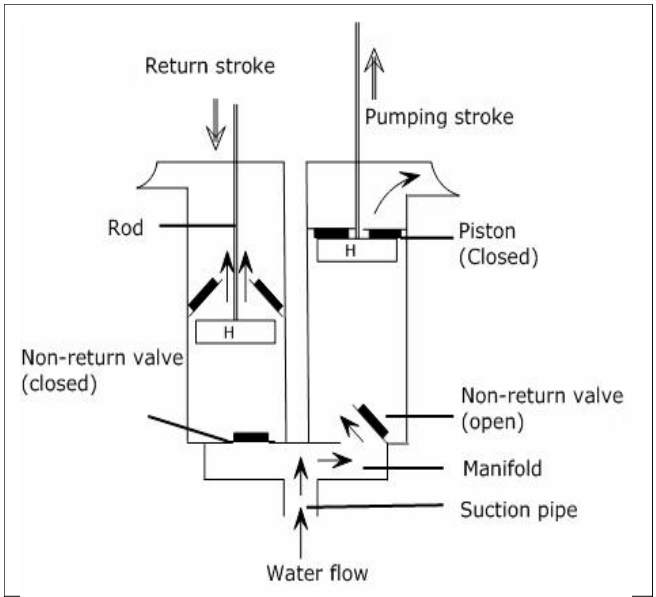

Fig. A : Operation of manual pump

This can be mathematically expressed as

$$F_{up} = F_s + F_d \quad (1)$$

where

F_{up} = force required to raise the water

F_s = Force required to raise water from water level to the cylinder by suction.

F_d = Force required to force water through delivery pipe.

Now , equation 1 can be written as

$$F_{up} = \varpi H_s . A + \varpi H_d . A\ (A - a)\ (kg) \quad (2)$$

where,

w= density of water in kg/m^3

H_s= Suction head (m)

H_d= Delivery head (m)

A= Cross sectional area of piston (m^2)

a= Cross sectional area of piston rod (m^2).

Volume of water discharged during the up stroke will be

$$V_{up} = (A - a).S\ (m^3) \quad (3)$$

where,

V_{up}= Volume of water discharged during the up stroke

S= Stroke length (m).

During the down stroke the water from the lower side of the piston goes to the top of the piston through the piston valve. The non return valve at the lower side of the cylinder remains closed. Therefore, force is required to raise this excess water against delivery head.

Force required to lower the bucket will be :

$$F_{down} = wH_d a\ (kg) \quad (4)$$

where,

F_{down} = Force required to lower the bucket.

Volume discharged during down stroke will be:

$$V_{down} = a.S\ (m^3) \quad (5)$$

where,

V_{down}= Volume of water discharged during the down stroke.

$$\text{Horse Power} = \frac{\omega QH}{75}$$

where,

$$Q = \text{Average rate of flow} = \frac{V_{up} + V_{down}}{2} \text{ x } N$$

where N = speed of crank in RPM.

$$Q = \frac{A \text{ x } S \text{ x } N}{60} \quad (6)$$

therefore

$$\text{Horse Power} = \frac{\omega QH}{75} = \frac{\varpi \text{ x } A \text{ x } S \text{ x } N \text{ x } (H_s + H_d)}{4500} \quad (7)$$

Using the equations 1 to 7, power requirement, head discharge relationship for both the pumps were estimated.

Participatory action research of the pumps was carried out in association with Krishi Vigyan Kendras (KVK).

Table A: Pumps subjected to testing

Pump	Type	Source	No of cylinder	Cylinder length (mm)	Cylinder bore(mm)	Suction bore (mm)	Mode of operation
Pump -1	Hand operated	Fabricated at AAU	Single	300	225	70	Operated with handle by one or two person
Pump -2	Pedal operated	KB pump (IDEI 2013)	Double	300	88.9	50	Single person pedal operation

Farmers with landholding size of less than 1 ha located in shallow water table areas (water table within 6 m from ground surface) and without any mechanical source for water lifting were selected. Farmer's expectations from a manual low lift pumps were collected through a questionnaire. Based on the questionnaire parameters for participatory assessment were chosen. Both the pumps were then demonstrated independently before 100 farmers and they were asked to give score of 0-10 (10 indicating the best and 0 the worst) against each of the parameters. The pump that scored better was tested in farmer's field for its efficacy in irrigating different crop through farmer's participatory action research. Water used and yield of crop was recorded and water use efficiency and benefit cost ratio was estimated.

RESULTS AND DISCUSSION

Fig. 1 shows the head discharge relationship of pump-1. The graph indicates a clear trend of decrease in discharge values with increase in total head for both single person and two person operation. The regression equations relating to discharge and head were " $Y_1 = 3.67 - 0.40 X_1$ " (for single man operation) and $Y_2 = 6.59 - 0.68 X_2$ (for two men operation) where "Y" indicates discharge value and "X" indicates total head. Correlation coefficient for the relation when single and two men operation were employed were (-)0.88332 and (-)0.99529, respectively. Discharge variation in high head is also prominent in one man operation (Fig. 1) This is because of increased effort required by a single person while pumping water from a greater depth.

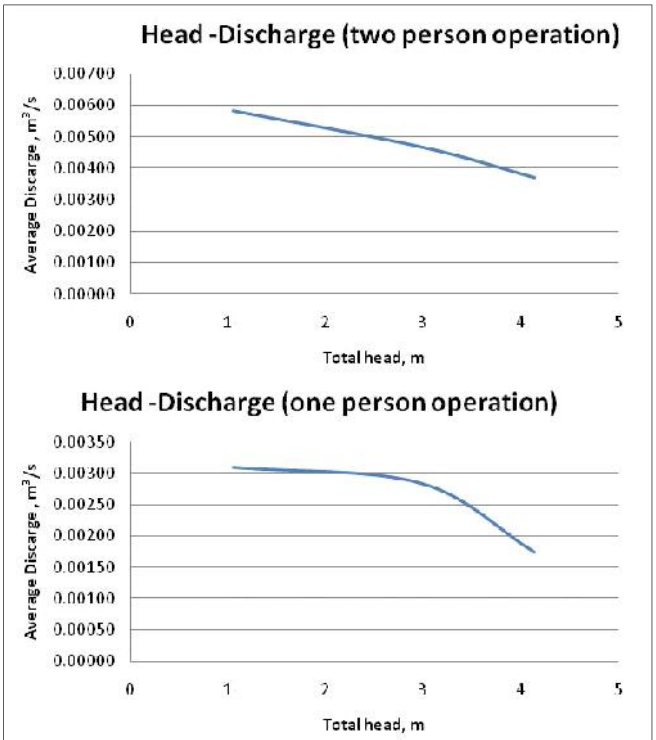

Fig. 1 : Head discharge relation of pump-1

Discharge head relationship of pump-2 has been presented in Fig. 2. It shows a clear trend of decrease in discharge values with increase in total head. The regression equations relating to discharge and head was

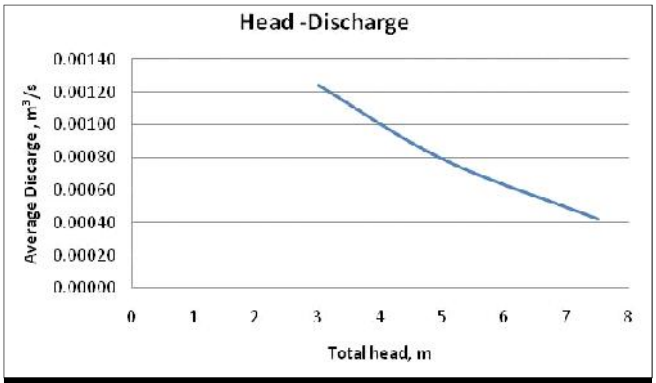

Fig. 2 : Head discharge relation of pump-2

"Y= 1.752- 0.18 X" where "Y" indicates discharge value and "X" indicates total head. Correlation coefficient for the relation was (-) 0.9922. The head discharge relationship showed a decreasing trend of discharge with increase in total head. Variations of discharge and power requirement of the pumps estimated from equations developed (1-7) are presented in Table 4. An average person can sustain an average output of about 75 watts (Eugene *et al.*, 2007). On that basis it may be concluded that pump -1 with single person operation may be operated with 10 RPM and can be used to draw water up to a total head of 5 m only . With two person operation this can be used up to 5m head with 10 RPM or up to 3m head with 20 RPM where as Pump-2 can be used up to 15 m head with 50 RPM. Although pump-1 is capable of more discharges pump-2 appeared to be better in terms of capability to draw water from greater depth and operator's comfort. This may be because of utilization of the leg muscles for pedaling action which might have enabled the operator to throw his or her weight behind the effort in order to gain further pedal pressure.

Participatory assessment:

Results of participatory assessment of the pumps are presented in Table 2. The ranking parameters were based on the questionnaire collected from farmers. In most of the parameter, pump-2 scored better except for discharge. This pump being pedal operated farmers might have found it easier to operate. Pedal pump may also be operated by single person that may be another reason for preference. Pedal pump is light and pump section can be easily carried to the field and

that is why farmers might have preferred for field security. The farmers preferred pump *i.e.* pump-2 (KB pump) was tested in farmers field through a farmer's participatory action research programme during the year 2012 and 2013. The location of the farmer's participatory action research and crops taken are shown in Table 3. The crops were chosen by the farmers themselves on the basis of local condition like input availability and market. The yield and water used and B:C ratio of the crop irrigated through participatory action research are presented in Table 4

Highest benefit cost ratio was recorded in tuberose grown in Nalbari district (8.50) followed by sugarcane (6.82) in the same district. This may be because Nalbari district is located close to Guwahati , the only big city of Assam, and tuberose flower and sugarcane has ready market there. Framers probably considered this aspect while choosing the crop and thereby earned good return on investment. Highest increase in yield over farmer's practice was recorded for ridge gourd (78.88) grown in Sonitpur district followed by knolkhol (62.56) grown in Sonitpur and Nalbari district. This may be because ridge gourd plating time (January to May) coincide with rainless period in Assam. During this period evpo-transpirational requirement of plants are at its highest. If the plants are not adequately irrigated productivity suffers. This might have contributed to the highest increase in yield of pedal pump irrigated ridge gourd over farmer's practice

Table 1 : Comparison of variations of discharge and power requirement with respect to crank speed ,N and total head, Q

Speed of crank, N, RPM	Discharge, Q,m^3/s		Total head , m	Power requirement for pumping, watt	
	Pump-1	Pump-2		Pump-1	Pump-2
10	0.0026510	0.0000989	3	79.09	2.95
			5	131.83	4.92
			7	184.56	6.89
20	0.0053014	0.0001978	3	158.19	5.90
			5	263.66	9.84
			7	369.12	13.77
30	0.0079522	0.0002967	3	237.29	8.85
			5	395.49	14.76
			7	553.68	20.66
50	NP	0.0004946	3	NP	14.76
			5	NP	24.60
			7	NP	34.43
			9	NP	44.27
			11	NP	54.11
			13	NP	63.95
			15	NP	73.79

NP: Not possible

Table 2 : Participatory ranking of the pumps

Sr. No.	Ranking parameter *	Pump-1	Pump-2
1.	Ease of operation	323	398
2.	Total head	212	402
3.	Discharge	396	336
4.	Field security	246	426
	Total	1177	1562

Table 3: Farmer's participatory action research in pedal pump : location and crop

Sr. No.	District	Location	No. of units
1.	Sonitpur	Napam Chapori (Block: Balipara)	4
2.	Dhubri	Bowalkamri (P-III) (Block: Nayer Alga), Bowalkamri (P-II) (Block: Mahamaya), Piazbari (Block: Mahamaya)	5
3.	Nagaon	Dakarghat (Block- Batadrawa, Takawbari (Block- Khagarijan), Sonaibal, (Block- Bajiagaon)	4
4.	Nalbari	Balitara, (Block- Borigog Bonbhag), Panigaon (Block- Pashim Nalbari), Sariahtoli (Block: Pub Nalbari)	4
5.	Kamrup	Kulhati (Block- Hajo), Nahira, (Block- Rampur), Bartari, (Block- Rampur)	4

Table 4 : Yield, irrigation water, Field WUE and B:C ratio of crop grown with pump-2

Location	Crop	Avg. yield(kg/ha)		% increase in yield	Irrigation water, cm	Field WUE, kg/ha-cm	B:C ratio
		Farmer's practice	With pump-2				
4,5	Cauliflower (Var Snow white)	15525	17535	12.95	7.2	2435.42	3.16
1, 4,5	Cabbage Var. Golden acre)	17300	23125	33.67	6.5	3557.69	2.64
1,4	Knolkhol (Var. white vienna)	4260	6925	62.56	8.3	834.34	2.96
4	Bottle gourd (Var. local)	9500	13500	42.11	7.1	1901.41	3.27
4	Potato(Var. Kufri Jyoti)	9652	15300	58.52	11.0	1390.91	4.21
4	Palak (Var. local)	7000	10200	45.71	8.0	1275.00	4.09
4	Pumpkin (Var. local)	5500	8400	52.73	5.2	1615.38	3.39
4,5	Brinjal (Var. local)	11587	15400	32.91	10.6	1452.83	3.24
1,4,5	Tomato (Var Avinash)	26126	33542	28.39	15.0	2236.13	3.56
4	Sugarcane (Var. local)	6700	8215	22.61	12.2	673.36	6.82
3,4,5	Toria (Var. TS-38)	875	1354	54.74	2.5	541.60	3.04
4	Tuberose (Var. local)	16120	21546	33.66	11.5	1873.57	8.50
1	Ridge gourd (Var. local)	5213	9325	78.88	6.69	1393.87	4.86
1	Cucumber (Var. local)	3652	5619	53.86	6.35	884.88	4.01
1	Maize (Var. local)	2562	3845	50.08	9.2	417.93	2.59
2,3	Summer rice (var Dishang)	4425	5925	33.90	33.0	179.55	2.23

which is dry land farming or manual hand watering. The reason for knolkhol which is planted in November to February may be similar. Cabbage grown in Sonitpur, Nalbari and Kamrup district yielded highest field WUE (3557.69 kg/ha-cm) followed by cauliflower (2435.42 kg/ha-cm) grown in Nalbari and Kamrup district. Cabbage and Cauliflower both being cole crop might have responded well to regular irrigation through manual low lift pump that produced more yield and subsequently better field WUE. The lowest field WUE (179.55 kg/ha-cm) and B:C ratio (2.23) was observed in summer rice grown in Nagaon and Dhubri district which was followed by Maize grown in Sonitpur (417.93 kg/ha-cm and 2.59). From Fig. 1 , 2 and Table 1 it may be inferred that technically it is feasible to achieve up to 0.0004946 m^3/s (0.494l l/s) discharge while drawing water from a depth of 3- 15 m through a crank speed of 50 RPM using a pedal operated pump. From Table 4 it may be inferred that best result in terms of yield and profit may be obtained if such pedal pumps are used to irrigate flowers and vegetables only.

Conclusion:

Participatory testing of hand operated low lift pump fabricated at Assam Agricultural University, Jorhat and commercial pedal operated pumps (Brand KB) was done during 2011-13. Results from testing indicates that though fabricated hand operated pump was capable of drawing more water, the power requirement for pumping was high. Participatory assessment by farmers also indicated more preference for commercial pedal operated pump because of ease of operation, total head and field security. Crops grown using pedal operated pumps in 5 districts of Assam as part of the participatory assessment resulted in increase in yield, WUE and profit in terms of B:C ratio. For best results, pedal pump may be adopted in shallow water table areas for irrigating flowers and vegetables only. Pedal operated pump may provide the much needed water source for irrigation for small and marginal farmers of Assam. This will enable them to switch over from less remunerative dryland crop to profitable high value irrigated crop.

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