Progress. Agric. 11 (1 & 2) : 207 - 213, 2000

Reprint
ISSN 1017-8139

PERFORMANCE OF INDIGENOUS WATER LIFTING DEVICES USED IN BANGLADESH – A CASE STUDY IN MYMENSINGH DISTRICT

M. A. Haque[1], M. D. Hussain[1], C. K. Saha[2] and M. I. N. Khan[3]
Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh

ABSTRACT

This study was carried out at field level to test and evaluate the performances of two manually operated, widely used indigenous water lifting devices, namely, *Don* and Swing Basket. For heads up to 0.75 m the *Don* produced higher discharge than the Swing Basket. When the lift height was increased further (upto 1.25 m) the discharge of the *Don* went down rapidly. Power requirement by both devices increased with the increase of head, and at a particular head, power requirement by the Swing Basket was found to be much higher than that of the *Don*. The efficiency of the *Don* was found to be higher than that of the Swing Basket. The highest efficiency of the *Don* was 46.44% at a head of 0.75m and an average discharge of 3.47 lit/sec, whereas that of the Swing Basket was 18.25% at a head and average discharge of 0.75 m and 3.43 lit/sec respectively. Average energy requirements of the *Don* and the Swing Basket were found to be 2.25 and 5.47 MJ/ha-cm, respectively. Average water lifting cost per unit volume of water was found to be Tk. 1.04/ m^3 and Tk. 1.42/ m^3 for the *Don* and the Swing Basket, respectively.

Key Words : Performance, Indigenous, Don, Swing basket

INTRODUCTION

The economy of Bangladesh is predominantly agrarian. Irrigation is an important input to intensive cultivation of HYV crops as required to attain self sufficiency in food production for the 120 million people (BBS, 1995). Farmers traditionally use different manually operated indigenous water lifting devices namely, *Don*, Swing Basket etc. for irrigation. The *Don* is made of low quality wood and Swing Basket is made of bamboo mat.

Though different power pumps are being used to harness ground water, manually operated water lifting devices still play a major role in irrigating small fragmented fields owned by the poor farmers of the country. Manually operated indigenous water lifting devices are used in irrigation for lifting surface water. According to the Fourth Five Year Plan, 1990-95 (Planning Commission, 1990) of the country, an area of 0.2 million hectare of land was estimated to be brought under irrigation coverage by the traditional methods to assist in increasing the land productivity in order to reduce poverty level of the poor farmers.

Although the usage of power pumps, shallow and deep tube-wells is increasing, the rate is still very slow due to low buying capacity of users, fragmented plots, socio-economic constraints, lack of spare parts, repair and maintenance facilities, high operating cost, etc. (Islam *et al.* 1981). Farmers in Bangladesh are not a homogeneous group but are endowed with different resources of land, labour and capital. Irrigation technology should reflect this diversity. At present 70% of farm households cultivate less than 1 hectare. Small farmers like these, with large reserves of family labour, are the potential users of manual pumps and indigenous water lifting devices (Orr *et. al,* 1991).

Normally in lying low lying areas like *Bil, Haor* etc. with sufficient reserves of surface water or in areas where natural canal flows, farmers mostly prefer to use indigenous water lifting devices like *Don*, Swing Basket, etc. to irrigate their land (Haque, 1995). It was reported that about 13% of the total irrigated area was irrigated by *Dons*, Swing Baskets etc. in Bangladesh (BBS, 1995). In terms of area irrigated by indigenous methods, the "*Don*" ranks the first and the Swing Basket the second (Ahmed *et al.*, 1986).

Therefore, a study was carried out with the following specific objectives :

i) To test and evaluate the on-farm performances of "*Don*" and Swing Basket.

ii) To assess the energy requirement and cost involved in lifting water by these devices.

MATERIALS AND METHODS

This study was carried out at the rice growing belt of Sarchapur village at Haluaghat Thana and Goneshampur village at Mymensingh Sadar Thana where *Don* and Swing Basket are being used for lifting irrigation water from canals. Both the

[1]Assistant Professor, [1]Professor, [2]Lecturer and [3]Post Graduate Student, Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh

devices were tested at different heads to evaluate their performances. Fig. 1(a) and Fig. 1(b) show the pictorial view of the *Don* and dimensions of the Swing Basket respectively and also dimensions of *Don* and Swing Basket are shown in Table 1 and Table 2, respectively. Operation of the devices were done under normal and as usual field conditions. Each test was replicated five times. In each term the time of operation, no. of strokes, discharge per stroke, discharge per second, force required per stroke were measured. The average of the five readings was taken as test data. The particular Swing Basket and the *Don* under study were selected as the representative of most of the devices with their dimensions available in the locality.

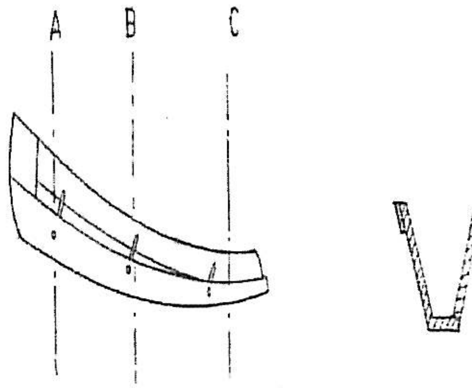

Fig. 1(a) Pictorial view of *Don* X-section

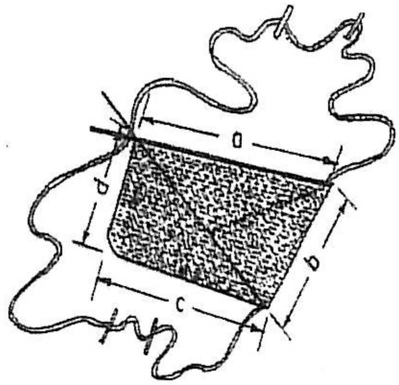

Fig. 1(b) Dimensions of Swing Basket

Operation of the devices

Don

It is one of the most ancient manually operated water lifting devices used to lift surface water for irrigation. Many of them are made of palm trees, but wooden and steel ones are also used. This is a mini boat shaped trough, closed at one end and open at the other (Fig. 1a). The closed end of the trough is tied with a rope or chain to a long bamboo, which is pivoted as a lever on a post. A counter-weight, a large stone or a ball of dried mud, is tied to the other end of the lever. The open end of the trough is hinged at the discharge point. The other end of the trough is dipped into water by applying the body weight and force applied by the operator. Water is lifted mostly by the action of the counter-weight on the beam in addition to a upward pull by the operation and is discharged automatically through the open end.

Table 1. Physical characteristics of the Don under study

Length, cm	Upper width, cm			Depth, cm			Weight, kg	Material	Life, Yr.
	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C			
405	20	30	17	16	17	14	22	wood	4-5

Table 2. Physical characteristics of the Swing Basket under study

Different measurements, cm				Weight, kg	Material	Life, month
a	B	c	d			
62	55	50	32	2.0	Bamboo chip	5-6

Analysis of forces acting on the Don

At the rest position-

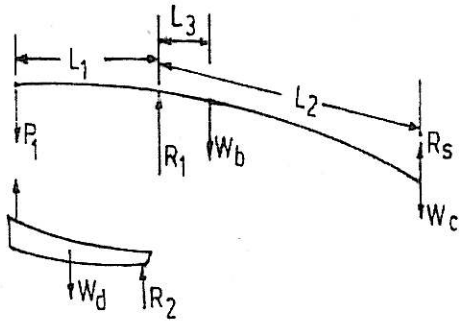

Fig. 2 (a) Free body diagram of *Don* at rest position

$$P_1 + W_b + W_c = R_1 + R_s$$

or $P_1 + W_b = R_1$ [since $W_c = R_s$]

Where,

P_1- Pull on the rope, kg
R_1- Reaction force on the post, kg
W_b-Weight of bamboo lever, kg
W_c- Counter-weight, kg
R_s- Reaction force on the counter-weight, kg

At the downward stroke position-

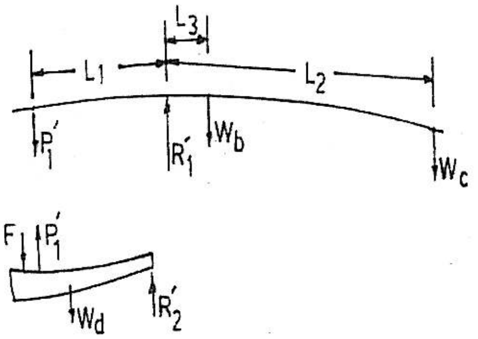

Fig. 2 (b) Free body diagram of *Don* at downward stroke position

$$P'_1\, L_1 > W_c L_2 + W_b L_3$$

or, $P'_1 > (W_c L_2 + W_b L_3) / L_1$

or, $F > (W_c L_2 + W_b L_3) / L_1$ [since $F = P'_1$] ...... (2)

Where,
L_1, L_2, L_3 – arms of the forces acting on the beam from the post, m
F – downward force exerted by the operator on *Don* to dip it into water, kg
P'_1 - Pull exerted on the rope due to F, kg

At upward stroke position –

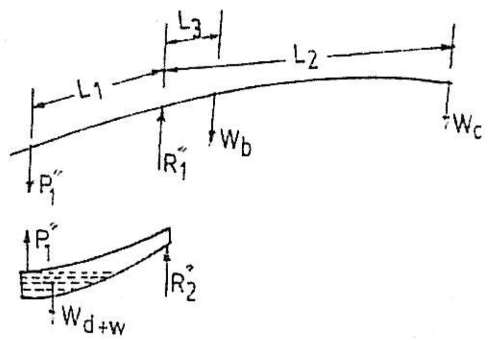

Fig. 2(c) Free body diagram of *Don* at upward stroke position

$$P''_1 = W_{d+w} - R''_2 \quad .... (3)$$

Where,

P''_1 - pull on the rope, Kg

R''_2 - reaction force on the open end of *Don*, kg

W_{d+w} - Weight of water-loaded *Don*, kg

As the *Don* goes upward, center of gravity of the water-loaded *Don* moves rightward.

Again , $W_c L_2 + W_b L_3 = P''_1 L_1$ ....(4)

This relation exists for the optimum system in relation to the forces applied (during upward and downward strokes) by the operator. If the L.H.S. of the equation is greater than the R.H.S., it will need no effort to lift the water-loaded *Don* but a greater effort will be required during downward stroke to dip the *Don* into water. So, from the above equation, the optimum counter-weight will be:

$$W_c = (P''_1 L_1 - W_b L_3) / L_2 \quad .... (5)$$

Though the operation of a *Don* is a dynamic process, for simplicity, analysis of forces acting on the *Don* are shown considering a particular static condition.

Swing Basket

Another major type of indigenous surface water lifting device is the Swing Basket. It consists of a basket or a shovel like scoop to which four ropes are attached (Fig. 1b and 11). Two operators stand facing each other and swing the basket to fill in water. The basket is then raised upto the field surface where it discharges to the field channel by the action of operators.

MEASUREMENTS

Discharge

Water discharge from a *Don* and was collected in a steel drum of 100 liter capacity and the time required to fill it was noted. Then the discharge per second was calculated. The discharge of the Swing Basket was similarly determined.

Head

Different heads were selected on the basis of different heights of the canal bank. The canals of the Sarchapur village and Goneshampur village permit a considerable range of bank heights at different locations nearby. Head was measured by a measuring tape from the water surface of the canal to the discharge level on the ground (crop field).

Force

Forces required to operate the devices were measured by a pull type spring balance. Force measuring techniques for both the devices are shown in Fig. 3.

Total force applied per cycle by the operator in operating a "*Don*" is

$$F = F_1 + F_2$$

Where, F_1 - Force on downward stroke, N
F_2 - pull on upward stroke , N

In operating a Swing Basket, total force applied by two operators can be estimated as

$$F = 2 (F_1 + F_2)$$

Where, F_1 , F_2, - Pulls on both the ropes of either side, N

Time and Linear Measurements

Time was recorded with the HEUER stopwatch which can record upto 0.2 second. All the linear measurements were done by a measuring tape.

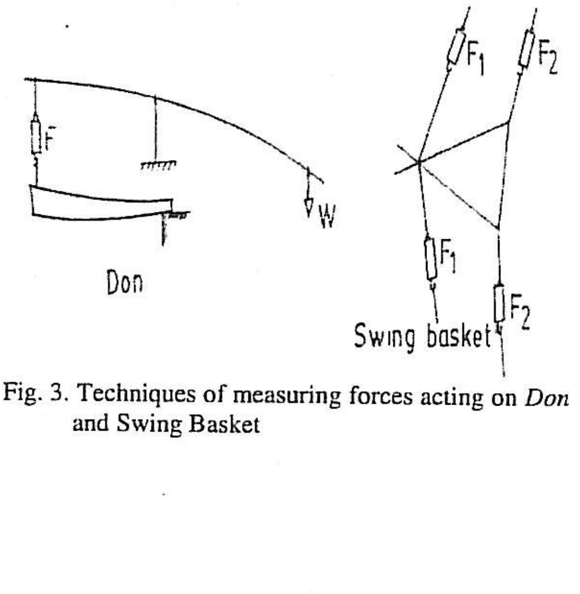

Fig. 3. Techniques of measuring forces acting on *Don* and Swing Basket

Work, Power and Efficiency

Abdullah (1986) tested performance of some manually operated pumps to find out their suitability for use in irrigation. Definition of these parameters are given below.

Work Input per effective stroke – It is defined as the force applied to the device multiplied by the stroke length or distance through which the device moved in the direction of the force applied.

i.e. , $W_i = F \times S$ (J)

Where, W_i - Work input per cycle or stroke, J
F – average total force applied, N
S – stroke length, m

Work output by the device per cycle – This defined as pressure equivalent for lifting up water upto a height h, multiplied by the volume of water delivered per effective stroke.

i.e., $W_o = P \times V$

$= \rho ghV$ (J) [Since $P = \rho gh$]

Where ,
W_o - work output per cycle, J
P - pressure exerted to water, N/ m^2
V - volume of water lifted per cycle, m^3
ρ - density of water, kg/ m^3
h - lift height, m
g -gravitational acceleration, m /sec^2

Power Input to the Device per Cycle – It is the total work done per cycle or stroke during continuous operation divided by the time taken to complete the cycle or stroke.

i.e. , $P_i = (F \times S) / t$

where, P_i - power input, W
t – time taken to complete the cycle or stroke, sec

Water Power Output – It is defined as the useful work delivered by the device per second.

i.e. , $P_o = W \times Q \times H$ (W)

where, P_o - water power out put, W
W - specific weight of water, N / m^3
Q - discharge rate, m^3 / sec
H - head, m

Efficiency of the device – It is defined as the ratio of useful work output by the device to the total work input to the device,

i.e. , $\eta = \{(\rho ghV) / (F \times S)\} \times 100$
Where, η - efficiency of the device, %

Energy Required in Lifting Unit Volume of Water – This may be defined as

$$E = (F \times S) / V$$

Where, E - energy required per unit volume of water, J/lit
V - volume of water lifted per cycle, lit

Ergonomic Aspects

Due to some constraints to measure different parameters of human body, the attempt was confined to record only the pulse rate of the worker and discomforts encountered at different parts of work's body. Pulse rate (beat /min) was recorded simply by counting pulmonary arterial circulation.

Cost of Lifting Water : Cost involved in lifting unit volume of water by *Don* and Swing Basket were calculated following the procedure suggested by Molenaar (1956).

Work Schedule: Farmers usually operate these devices for 10 to 15 minutes at a stretch and then take a break of 5 to 6 minutes in their usual practice to irrigate their land. These devices were operated continuously for 1 hr to see the effect of time upon speed (stroke / min) and pulse rate.

RESULTS AND DISCUSSION

Head- Discharge Relationship

An inverse relation between head and discharge of the devices was observed i.e., discharge decreases as the suction head increases (Fig. 4). For the *Don* and the Swing Basket, falls of discharge were found to be 53% and 29 %, respectively considering the lowest (0.5 m) and the highest lift (1.25 m) during test period. At low head (upto 0.75m), discharge of *Don* was found to be higher than that of the Swing Basket. But when the head increased further, discharge of the Swing Basket was found to be higher than that of the *Don,* as the operating speed of the former was higher than that of the later.

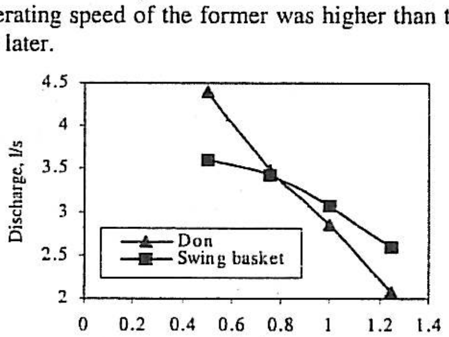

Fig. 4. Head-Discharge relationship of Don and Swing basket

Power Input- Discharge and Power-Head Relationship

Fig. 5 and Fig. 6 show the relationship between input power against discharge and head, respectively. Fig. 5 shows that power input decreases with the increases in discharge. Apparently, this may seem unusual which is clarified in Fig.6 by plotting power against head. In this figure it is evident that power increases with the increase in head. The antithesis in the relationship between the power-discharge and power-head is due to the fact that power is directly related to the force required to operate the pump and the force is proportion to head. As the head increases force required also increases but discharge decreases. So an inverse relation exists in Fig. 5.

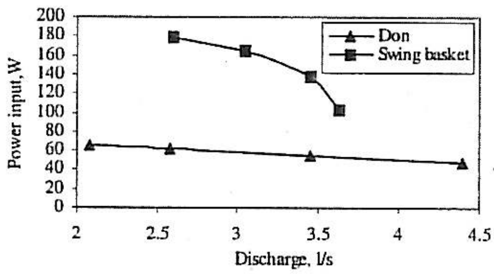

Fig. 5. Power-Discharge relationship of Don and Swing basket correeponding to different heads

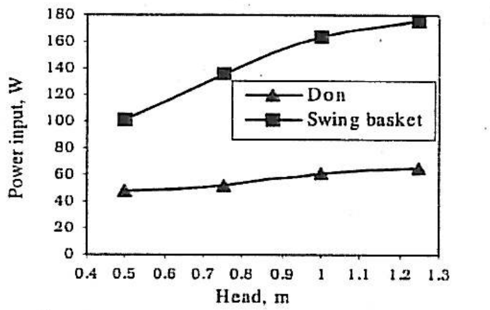

Fig. 6. Power-Head relationship of Don and Swing basket

Fig. 6 shows that as the head increases power input also increases. For the Swing Basket the increasing rate is much higher than that of the *Don.* This figure indicates an average increase of power, within the lowest and the highest head at which they were tested, as 42% and 84% for the *Don* and the Swing Basket, respectively. For the Swing Basket an increase of power input by 165% above that for the *Don* was found at an operating head of 1.25 m. This is because the Swing Basket needs two operators simultaneously.

Efficiency- Discharge Relationship

Fig. 7 shows the relationship between efficiency and discharge of the *Don* and the Swing Basket. It was observed that efficiency increased with the increase in discharge upto a certain limit and then began to fall with the further increase in discharge. Efficiency was observed to be less at low head although the discharge was high; also at high head the efficiency was found to be less due to high power requirement. Fig. 7 and Fig. 4 show that the optimum head at which the efficiency was found to be the highest is 0.75 m for both the *Don* and the Swing Basket. For *Don* and Swing Basket, the highest efficiencies were found to be 46 % and 18 %, respectively.

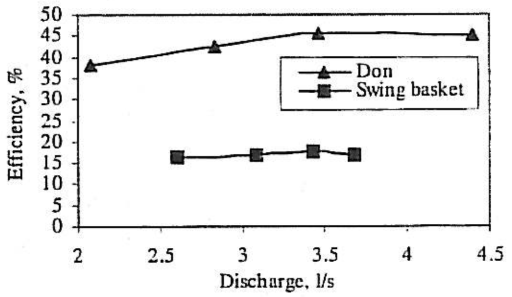

Fig. 7. Efficiency-Discharge relationship of Don and Swing basket

Cumulative Discharge

Fig. 8 shows cumulative discharge of *Don* and Swing Basket. These curves are plotted to show the comparative volume of water lifted by the devices at a certain head upto an working period of 2 hours. It was observed that the Swing Basket lifted 5 % more volume of water than the *Don* at a lift height of 1.00 m.

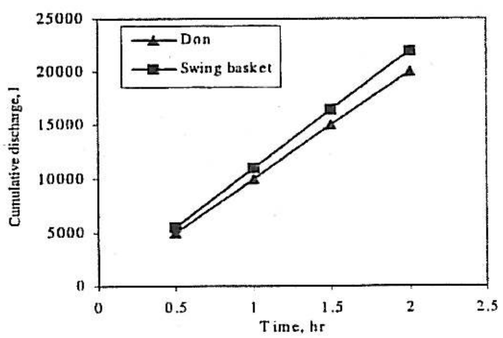

Fig. 8. Cumulative discharge of Don and Swing Basket

Ergonomic Aspects

Ergonomic study for the devices was confined to observed the pulse rate of the worker during operation, ease of operation, discomforts encountered and pain experienced in different parts of the body of the worker. Fig. 9 shows that the pulse rate of the worker increased rapidly within 15 to 20 minutes of operation and then reached the peak after 1.5 hours of continuous operation which were found to be 120 and 122 in operating the *Don* and Swing Basket, respectively. Pulse rate of the worker came back to normal within 10 minutes during the resting period.

It was observed that the working speed of the devices dropped down as the working time increased.

Fig. 9 depicts the relation of working speed with time for *Don* and Swing Basket at a head of 1.00 m. Working speed and also drop of speed for the Swing Basket were observed to be higher than those of the *Don*. At the beginning of the work the working speeds were observed to be 5 and 23 cycle / minute for the *Don* and Swing Basket, respectively.

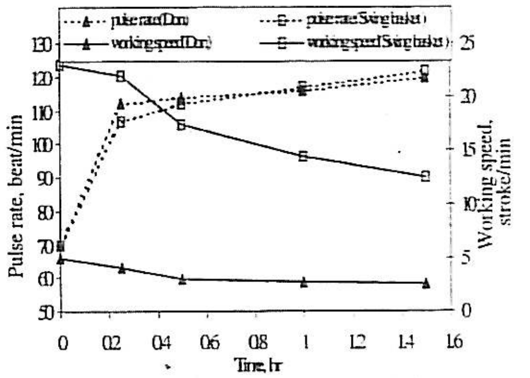

Fig. 9. Pulse rate and working speed in operating the Don and Swing basket (head 1.0)

Average energy requirements in lifting unit volume of water were found to be 2.25 and 5.47 MJ/ ha-cm for *Don* And Swing Basket, respectively at a lift height of 1 m. At this lift height, *Don* required about 59 % less energy than the Swing Basket, as the latter one requires two labourers simultaneously to operate.

Among the physical problems experienced by the worker in operating the *Don* are pain and strain at both the elbow, right knee and ankle, and at the right shoulder as the right hand and right leg play the vital role in dipping and lifting it. In operating the Swing Basket, palm rupture occurs by the rope-grip and the operators feel pain on the fingers for continuous long operation. The operators also reported strain and ache at the chest, shoulder, loin and cuff muscles.

Cost of lifting unit volume of water

This cost was calculated on the basis of lifting per ha-cm volume of water by the devices. Fixed costs in lifting per ha-cm volume of water dropped down as the volume of water lifted per year increased. This phenomenon is shown in Fig. 1(a) in lifting surface water at a lift height of 1.25 m. It was observed that cost of lifting per ha-cm volume of water was less for the *Don* as compared to that of the Swing Basket. This was because Swing Basket needed two operators that in turn increased operating cost. In lifting 10 ha-cm volume of water annually. Cost of lifting per ha-cm of water by the *Don* is 21 % less as compared to that of the Swing Basket. The average water lifting cost was found to be Tk. 1.04 and Tk. 1.42 per m^3 of water for *Don* and Swing Basket, respectively.

CONCLUSIONS

Don and Swing Basket are the widely used indigenous water lifting devices for low cost irrigation in Bangladesh. From the performance study, it may be concluded that the discharge form the *Don* is higher at lower head (upto 0.75 m) than that from the Swing Basket. For further increase in head, discharge of *Don* reduces rapidly than that of the Swing Basket. Power requirement by the Swing Basket was much higher than that by the *Don* at any particular head within the range of head considered in the study. Pumping efficiency of the *Don* was found much higher than that of the Swing Basket.

Average energy requirement in lifting per ha-cm volume of water by the *Don* was found to be nearly half of that of the Swing Basket. Also the average cost of lifting unit volume of water was found less for *Don* than that of the Swing Basket. So, *Don* can play an important role in lifting surface water for low cost irrigation to supplement the mechanized irrigation .

REFERENCES

Abdullah, M. 1986. Performance evaluation of manually operated pumps for small for scale irrigation in Bangladesh . M.Sc. Thesis submitted to the Cranfield Institute of Tech., Silsoe College, Bedford, England. pp. 64.

Ahmed, M. and Khan C. M. A. 1986. Improvement of manually operated water lifting device. Agricultural Mechanization in Asia, Africa and Latin America. 17(1) : 51-54

BBS. 1995. Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Dhaka. pp. 646.

Haque, M. A. 1995. On farm performance of manually operated water lifting devices used in Bangladesh . An M. Sc. Thesis submitted to the Dept. of Farm Power and Machinery, BAU, Mymensingh, Bangladesh. pp. 92.

Islam, M. S., Mazed, M. A. and Roy K. C. 1981. Comparative performance of different types of manual pumps, Agricultural Mechanization in Asia, Africa and Latin America, Summer 65-68.

Molenaar, A. 1956. Water Lifting Devices for Irrigation. FAO Agricultural Development Paper No. 60, FAO, Rome. pp. 73.

Orr, A., Islam, A. S. M. N. and Barnes G. 1991. The Treadle Pump: Manual Irrigation for small farmers in Bangladesh. Published by RDRS, Dhaka, Bangladesh. pp. 96.

Planning Commission. 1990. The Fourth Five Year Plan (1990-1995). Planning Commission, Govt. of the People's Republic of Bangladesh, Dhaka.