PERFORMANCE COMPARISON OF SOME MANUALLY OPERATED WATER LIFTING DEVICES.

A Research Project

Submitted by

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In partial fulfilment of the requirements for the Degree of Master in Engineering

(Water Resources)

DEPARTMENT OF WATER RESOURCES ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY
DHAKA

August, 1985.

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

August 7, 1985

WE HEREBY RECOMMEND THAT THE RESEARCH PROJECT PREPARED BY MD. SHAFI UDDIN MIAH ENTITLED "PERFORMANCE COMPARISION OF SOME MANUALLY OPERATED WATER LIFTING DEVICES" BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN ENGINEERING (WATER RESOURCES).

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ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr.Md.Mirjahan Assistant Professor, Department of Water Resources Engineering for his guidance and encouragement. It is also a pleasure to acknowledge his thought and untiring help in all aspects of manuscript preparation, without which this research project would not have been brought to completion.

I am grateful to Dr.Abdul Hannan, Professor and Head of the Department of Water Resources Engineering for his help in all aspects.

I am thankful to Dr.M.Shahjahan, Professor of Department of Water Resources Engineering for his valuable correction in the project report writting.

I like to thank Dr.M.A.Mazed, Head of the Department of Ag.Engg.Division, BARI, Mr.Sirajul Islam, Senior Scientific Officer, BARI, Dr.Kh.Azharul Haque , Head of the Department of Ag.Engg. Division, BRRI, Dr. M.A.Mannan, Director General, BRRI, Joydebpur,Dhaka for helping me in data collection.

I extend thanks to Mr.M.Mofser Ali for taking great care in typing and also to those who indirectly helped me in collecting information.

Finally, I wish to compliment my family for encouragement during the period of my Post-graduate study program.

August 7, 1985.

MD.SHAFI UDDIN MIAH

ABSTRACT

Lift irrigation becomes necessary to utilize the ground water and shallow depth water resources. Water lifting devices for irrigation range from age old indegineous water lifts to highly efficient pumps. Utilization of lifting appliances driven by human energy can play an important role because of increasing shortage and rising cost of fuel energy. So, selection of the best device in term of rated capacity efficiency and economy is necessary.

Eleven water lifting devices have been studied in this research project. Head Versus Discharge data of these devices were collected from literature and pumping tests. Efficiency was calculated from the collected data. Discharge and Efficiency versus Head Curves were ploted and the maximum efficiency and discharge corresponding to this efficiency of each device were determined. Based on this discharge Benefit to cost ratio of the different devices was found out.

The possible devices within the lift range of 0-1.5 m are Dhone and Swing Basket. In this head range Dhone was found to be the most efficient device having discharge capacity 3 times and efficiency 5 times the corresponding values for Swing Basket. Moreover, Dhone was found to be highly economically attractive device.

The possible devices within the lift range of 1.5 to 4.5 m are BRRI Diaphram pump, M.L.K. Pump and Twin Treadle pump. In this range M.L.K. pump was found to be the most efficient device. The discharge of this device is 1.70 l/sec at the head of 4.00 m Corresponding to the maximum efficiency of 88%. BRRI Diaphram pump followed M.L.K. pump having discharge of 2.80 l/sec at the head of 3.20 m Corresponding to the maximum efficiency of 68%. Upto 3.00 m lift BRRI Diaphram pump was found to be the best device in term of rated capacity, efficiency and economy.

The possible devices within the range of lift from 4.50 to 7.5 m are Shaduf. Hand Tubewell, Rower Pump, One Man Operated Diaphram pump, Two Men Operated Gardening pump and Two Cylinder Reciprocating pump. When lifting of water is required within the range of 4.5 to 5.5 m Hand Tubewell was found to be the most efficient device but the benefit to cost ratio of Hand Tubewell was found to be slightly less than that of Shaduf. Upto the lift of 6.00 m. One Man operated Diaphram pump was found to be the best device in term of rated capacity, efficiency and economy. Rower Pump was found only the economically feasible device within the head range of 6.00 to 7.5 m. The other device within this head range are not found to be economically viable.

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CHAPTER - I

INTRODUCTION

1.1 General

In many developing countries the farmers have a long term tradition of using small scale irrigation system and surface water as their supply. Places where topography permits the most simple and efficient method to supply water to the land is by gravity flow. Areas where this is impossible, for example, where supply is from shallow groundwater, lifting becomes necessary. Traditionally human labour, animal, water and wind have been the power sources for water lifting. But in some areas there has been a tendency to replace the traditional device by modern pumping equipment. However, this trend is getting retarded because of increasing shortage and rising cost of fuel. Ever increasing demand of fossil energy for other sector would further intensify the efforts to improve and to develop reliable systems based on renewable energy sources.

More than 30 million water lifting devices are in operation for irrigation purposses in the developing countries and about 10 million devices utilizing human labour, animal, wind and hydropower (2).

The mean annual rainfall in Bangladesh varies from about 1524 mm in the western part of the country to almost 5080 mm in the north-east. There is a wide seasonal fluctuation with about 90 percent of the rainfall occuring in the five months of the monsoon period (May to September). Inspite of an overall abundance of rain, serious droughts do occur. There are instances of inadequate rainfall even during the monsoon season. The minimum rainfall during most of the dry season(October to March) is almost zero. Hence irrigation is necessary for year round cultivation.

Total land in Bangladesh is 35.3 million acres. Almost all of the arable lands (22.5 million acres) are cultivated. Irrigation only covers 19% of the total cultivated area in which 51% are irrigated by manual methods and rest 49% are by mechanical power driven methods (11). Although the irrigated area has been increased in the recent years, there is an immense scope of further expanding the areas. This will increase the cropping intensity and food production.

Improvement and extensive utilization of the water lifting devices driven by human energy can play an important role in expanding the irrigated acreage in the country. Water lifting devices driven by human energy have some important advantages in this country. Some of those are: (i) Human energy requirement for lifting water can be provided by the users in rural areas

(ii) the devices are labour intensive and require elementary technologies both of which are locally available;(iii) the capital cost of manual water lifting units are low;and (iv) compared to alternate forms of water lefting devices which are dependent on imported fuel, manual water lifting devices are little sensitive to inflation (1).

1.2 Objective

The purpose of this study is to compare the performance of various manually operated water lifting devices used in Bangladesh. The specific objectives are:

(i) to develop characteristic curves for each of the study devices based on data available in the literature and data generated by pump test;

(ii) to determine the optimum operating condition for each device;

(iii) to compare the efficiencies of the devices; and

(iv) to compare the economic efficiencies of the devices.

CHAPTER - II

LITERATURE REVIEW

A number of studies have been undertaken to familiarize the various indegineous water lifting devices in the developing countries (1,2,4,5). In most of the studies emphasis has given on either the general description of the devices or their performances at farmers level. No attempt has been made to compare the performances of various devices in terms of mechanical and economic efficiencies, Systematic studies on improvement of the design and operation of these devices are also lacking.

A brief review of some of the studies are given in the following paragraphs.

Ahmed,(1) undertook a study on the performances of some manual methods of irrigation in Bangladesh. In his study he identified the manual water lifting devices in operation in Bangladesh to estimate the potential contribution which manual devices can make in irrigation. As such he discussed about Dhone, Swing Basket, Hand Tubewell, Dug Well, Scoop, Sea-saw pump, Chinese, Chain and Washer pump, BRRI pump(Bangladesh Rice Research Institute), Rower pump and Archemedean Screw. He developed head versus discharge curves of Dhone, Swing Basket and Hand Tubewell. The data used were collected by field tests and measurements. He did not include input-output analysis in his study.

Mostafa,(2) conducted an investigation on the water lifting devices in the developing countries. The aim of his study was to familiarize the readers with different catagories of water lifting devices being used in developing countries. He described various devices driven by man, animal, wind, solar, biogas and fossil fuel power. Performance characteristic curve of Dhone and Swing Basket has drawn.

Khan (3) gave a general description of water lifting devices in Asia and the near east. He discussed about Dhone, Swing Basket, and MOSTI (Manually Operated Shallow Tubewell Irrigation). Head discharge curves of these devices had been drawn. He did not discuss the recently developed manual pumps which have been operating in Bangladesh.

Ghani, Islam and Khondokar (4) undertook a study to collect the different types of manually operated pumps available in the country for evaluation of their performances in order to select the best available design and to carry out further modification if necessary to improve their performances. In the report they shortly described six manually operated pumps such as BRRI Diaphram pump, Comilla Co-operative Karkhana pump, Dev BKB pump, No.6 Reciprocating pump, Rower pump and Twin-Treadle pump. They conducted pumping test for short range of head variation.

Islam and Mazed (5) conducted a research focussing on the comparison of performances of different types of manual pumps. In the report they described the various devices and included test results. Head vs. discharge curves for the study devices have also drawn in their report. They did not use pump efficiency as an index in the comparison. Nothing has been mentioned about the optimum operating conditions. They gave estimated cost of these manual pumps for comparison but complete economic appraisal has not been done.

CHAPTER - III

DATA COLLECTION AND ANALYSIS

3.1 Physical Characteristics of the Study Units

A number of manually driven water lift devices are being used in Bangladesh. The following devices have been selected for this study:

3.1.1 Dhone

3.1.2 Swing Basket

3.1.3 Shaduf

3.1.4 BRRI Diaphragm pump

3.1.5 M.L.K. Pump

3.1.6 Hand Tubewell

3.1.7 Rower Pump

3.1.8 Twin Treadle Pump

3.1.9 One Man Operated Diaphragm pump

3.1.10 Two Men Operated Gardening pump

3.1.11 Two Men Operated Reciprocating pump

Brief descriptions of these units are given in the following paragraphs:

3.1.1 Dhone

The Dhone is a manually operated boat shaped trouph, closed at one end and open at the other end. The length of Dhone varies from 3.8 meters to 5.3 meters. Longer Dhone is suitable for higher lift. The depth and width of the discharge end vary from 12.7 to 15.2 cms and 12.7 to 20.3 cms respectively and those of the intake end range from 17.8 to 22.9 cms and 17.8 to 25.4 cms respectively. The bottom of the intake end was made conical to minimize the bouyant force. The intake part was about 50 percent of the total length, slightly raised upward to make it easy of operation and to facilitate quick filling of the Dhone.

It is operated by one man with the help of a lever. The lever is eccentrically pivoted from the centre and hanged on the larger end of the lever in such a way that there exist sufficient slope in the Dhone for quick discharge of the lifted water. A weight, (a large stone or a ball of dry mud) is fixed to the shorter end of the lever. The operator puts his body weight on the closed end of the Dhone to filled with water from river or pond using his leg. He stands on a bamboo platform usually 15 cms above the water surface. When the Dhone is fill with water the operator removes his body weight and it is automatically lifted up owing to the counter weight on the other end of the lever.

The discharge of a Dhone varies with the lifted height, skill and efficiency of the operator. The range of lift for Dhone of length 5.1 meters and 3.8 to 5.1 meters are 1.0 to 1.2 meters and 0.9 to 1.0 meters respectively. The maximum lift height for single stage is 1.4 meters. The farmers increase the number of stages of Dhone with the increase of lift. Generally when the lift exceeds 1.5 meters the farmers arrange for next stage. It has been observed that the usual practices of the farmers is to go for 2-3 stages; however in some cases 4 stages may be found. The discharge characteristics of several designs of Dhone are recently measured under field condition. The discharge is 7.5 litre/sec for a lift of 0.8 m but it reduce to only 2 litres/sec for the left of 1.8 m. About 4-5 acres of dry season rice can be irrigated by one Dhone. The cost of construction and installation are about Tk. 600.

3.1.2 Swing Basket

The Swing Basket consists of a basket made out of bamboo or quite literally a normal tin bucket which is tied to ropes. Two persons stand on either side and swing the basket to raise the water and is discharged into the field channel.

Swing Baskets are made locally by farmer and are used for providing irrigation water to dry season rice. About an acre of dry season rice can be irrigated by a swing basket. The cross section or shape of a Swing Basket is a hollow cone. Generally farmers used a 51-56 cms square mat or G.I. sheet. The average volume of a Swing Basket is about 1.50 U.S. Gallon (5.7 litre). The water delivered per stroke varies from 5.3-4.0 litres at lifting height varying from 0.8 - 1.50 meters respectively.

Average period of work done at a stretch is 15-25 minutes. This method is the most laborious irrigation method practiced in Bangladesh because all the weight of lifted water is supported by the operators. Swing Basket is a very simple device and needs minimal repair. A swing basket costs about taka 75.

3.1.3 Shaduf

The shaduf is a counter balanced lift which can be used to lift water from a shallow dug well or a pond or ditch. Pitchers are some times used to lift water for irrigation from the dug well. The device consists of a lever which swings around pivot having counter weight on one side and pitcher fastened by rope on the other side. The operator pushes the pitcher into the water and pitcher is lifted up by the counter weight of the lever. Some times instead of counter weight of the lever one end of a bamboo is kept fixed on the ground and the elastic action of the bamboo is used to lift up the pitcher from the dug well. The frequency of the stroke depends on the depth of water, size of the pitcher and counter weight to lift up water. About $\frac{1}{3}$ of an acre of rice can be irrigated by this method.

3.1.4 BRRI Diaphragm Pump

It is a diaphragm type twin position displacement pump. Two pumps are installed over one platform and act as a single unit. Both the pumps have one common chamber. There is a one way valve allowing the water to enter into the suction chamber. The extended lift arms of pump are connected with the long operation handle by bolts. The operation handle is fitted on a stand and actuates over a fulcrum. This pump is recently midified to make it more simple and to reduce the cost and energy requirement and to improve longivity of the diaghragm by changing the rectangular shapted box to circular shaped box.

The performance test of commonly used manual pumps in Bangladesh the BRRI diaphragm pump performed better upto 3 meter head. Beyond three meter head it required too much energy which made it difficult to operate the pump even for a very short period. It has the discharge capacity of 3.90 l/sec at the head of 1.5 m which reduces to 3.50 l/sec when the head increased to 3 m. The estimated cost of the pump is taka 1,500. The operational and maintenance cost is very low. Two men is required to operate the diaphragm pump. After operation of a season repair needed is to change the rubber diaphragm.

3.1.5 M.L.K. Pump

This pumps is a double acting reciprocating pump. It is a manually operated pump developed by Mohammad Lukman Khan. All the parts of the pump including the pump cylinder is made of steel. The estimated cost of the pump is Taka 2,500. This pump can be operated by one or two persons. Maintenance and repairing cost is nearly 250/- Taka per year.

3.1.6 Hand Pumps

The No.6 pump is a cast iron lift pump used primarily for pumping drinking water. At present, its wide use is found in small scale irrigation projects. The pump cylinder has an internal diameter of 10.2 cms and the water chamber just above the pump cylinder is 12.7 cms. The piston of the pump is connected to a hand lever of 0.75 meter. The base of the pump is threaded to receive a threaded 3.8 cms galvanised steel pipe. The plunger of the pump consisted of one way valve and a bucket generally made from leather or plastic. The leather bucket are more durable but comparatively more expensive than plastic bucket. According to the information available for one season, generally two leather buckets or six plastic buckets are required. The discharge of a Hand Pump, varied with different factors such as depth of groundwater table, strength of the operator and age of the pump etc.

Hand pumps are used for irrigating mostly dry-season rice and vegetables. These are used for very small land holdings (smaller than ½ acre). The efficiency of an operator in pumping while sitting and using leg is better than while pumping in standing position. These pumps are extremely popular in areas where surface water is not available and ground water table is close to the ground. The cost for pumps, steel pipes and strainer including installation are approximately Taka 2,500. When PVC pipe and strainer are used then the cost reduces to Tk. 1,000. Annual maintenance and repairing cost is approximately Tk.100.

3.1.7 Rower Pump

The Rower pump is a manually operated reciprocating pump with 2"(5.1 cms) diameter PVC plastic pipe as the cylinder. The piston inside the cylinder is operated by pushing and pulling directly on a T-handle at the upper end of the piston rod. The pump is attached to the tubewell at an angle of 30^{o} with the land surface. A vacuum chamber is used to damp the velocity variation in the moving water column that occurs due to the reciprocating piston. Maintenance is a very easy task so that a farmer can easily check and service his own pump as needed. Primary maintenance would be expected on the piston on which a leather cup seal and rubber valve flap are fixed. On less frequent occassion the foot valve may needed to be examined. It has a rubber flap valve which can be removed and replaced quite easily.

The Rower pump operates with out cavitation upto about (8.5 m) pumping head. When the pump is used for irrigation a maximum (6.7 m) pumping head is recommended due to limittations of operator strength. The estimated cost of this pump with 7.6m PVC pipe and 2.5 m strainer is Taka 800. This pump is designed by Manonite Central Committee and Manufactured by Mirpur Agricultural Workshop and Training School. This Workshop supplies 2,000 Nos. of Rower Pump in the district of Kushtia and Dinajpur in the year 1982-83.

3.1.8 <u>Twin Treadle Pump</u>

Twin Treadle Pumps are made for irrigation both from sub surface and surface sources. This pump consists of some bamboo pieces and two cylinders. Body weights of the operators are used as power to operate the pump. Total body weights on treadles, legs and thigh muscles are effectively used to operate the pump. The spares of the pump are easily available. Rope and

Bucket are changed by the farmers, foot valve replaced by the local handyman. This pump is successfully operated with bamboo, PVC or G.I.Pipe. 12,000 number of Twin Treadle pumps are installed since invention in November, 1980. ⅓ to ⅔ acres of intensively irrigated rice and 1 to 2½ acres of dry crops such as wheat, potatoes or tobacco can be easily irrigated by this pump. The estimated cost of the pump is 400 to 500 Tk. completely installed with bamboo filter and bamboo tubewell bored to 4.5 cms (11).

Many groups are working (both men and women) in different villages of Takurgaon and Kurigram district due to the motivation of the Rangpur-Dinajpur Rehabilitation Service(RDRS) operated by the Lutheran World Federation (The Daily News, Feb. 14,1985).

Irrigation by this pump with bamboo tubewells developed by RDRS is a common sight in the villages of Thakurgaon and Kurigram districts. This low cost manual device is more useful than diesel pumps in increasing the production of small farmers. The treadle pump is estimated to have a life of 2 to 3 years. In order to alleviate the deterioration of the non submerged bamboo well casing RDRS has begun to treat that portion of the casing with a solution of borax, sodium di-chromate, copper sulphate, ammonium phosphate and acetic acid. This pump has a 25.4 cms stroke and the diameter of the pump cylinder are sized for the distance the water must be lifted in order to match the required pumping force to a man's optimum force in the treadle. A 7.6 cms diameter cylinder for 6 m lift, 8.9 cms cylinder for a 4.6 m lift, a 12 cms cylinder for a lift of 2.4 m and a 15 cms cylinder for 1.5 m lift from rolled 15/16 gauge mild steel (MS) sheet, Plunger rod is made from .95 cms MS rod fixed with plunger discs of 12 gauge MS sheet (6).

3.1.9 One Man Operated Diaphragm Pump

The body of the pump is an irregular shaped cast iron vessel having a rubber flap, the most important element of the pump. One man operate it with a long lever which raises and lowers the rubber flap to create vacuum. This pump gives a good discharge for low head. Cost of this pump is about Taka 1,800. Maintenance cost is very low. Change of rubber flap is required after one season operation. Maintenance cost is near about Taka 180 per year.

3.1.10 Two Men Operated Gardening Pump

It is a cast iron pump working in a reciprocating action. Cylinder of the pump is in a horizontal position. Alternate pulling and pushing mechanism is done with a 'T' shaped handle hinged to the driving piston. This pump is operated by two persons standing on the oposite sides of the pump facing each other. In a cylinder two buckets are fixed one oposite to the other with a single piston. When one person pulls the other pushes and thus alternately the operation goes on. Cost of this device is about Taka 1,500. Maintenance cost is very low. Only the buckets are needed to change after using this pump for one season. This require Taka 160 per year approximately.

3.1.11 Two Cylinder Reciprocating Pump

This is a cast iron pump. It is rested on four wheels for easy of movement. This pump is operated by two persons by raising and loering the piston with the help of a lever arm. The lever arm is fitted with a single 'T' shaped bar hinged at the centrally fixed cylinder. This pump costs Taka 2,000 and maintenance cost is low which is about 200 per season. The bucket is needed to change after using one season. Discharge of the pump is not satisfactory as compared to the others.

3.2 Data Collection

Data were collected from the previous study reports and also from the pump test.

3.2.1 Collection from Literature Sources

Head Versus Discharge data of Dhone, Swing Basket and Hand Tubewell as reported by Ahmed, K.U(1) were collected. The pump test data of Shaduf and Twin-Treadle pump were taken from the M.Engg. special study report prepared by Mostafa,M.G(2) and from the short consultancy report(6). The data on M.L.K. Pump and BRRI Diaghragm pump were taken from the annual research report of BRRI(7). All the relevant data are included in Table 3 to 9 Appendix-A.

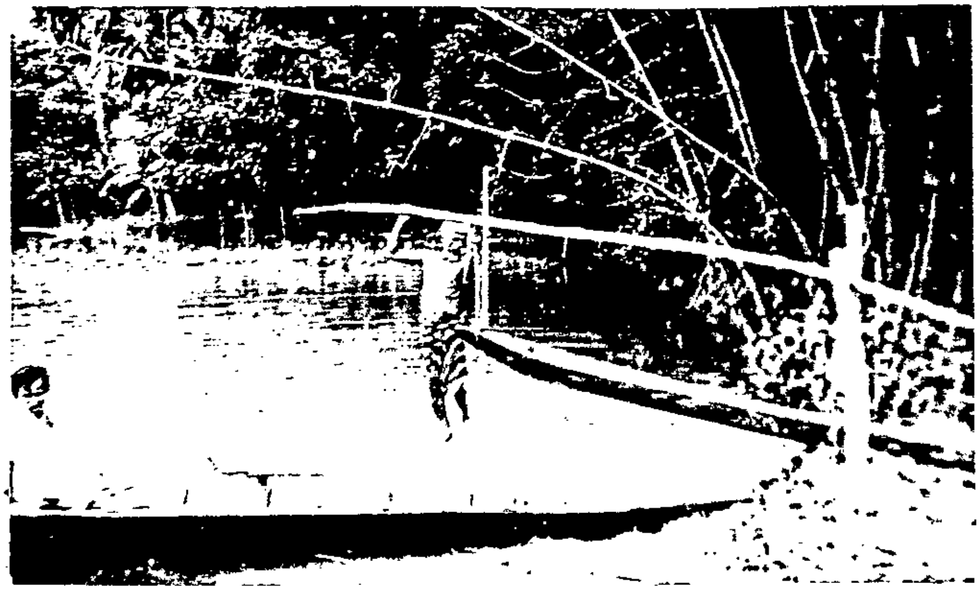

Fig.1 Dhoɇe in Operation

Fig.2 Swing Basket in Operation

Fig.3 Shaduf in Operation

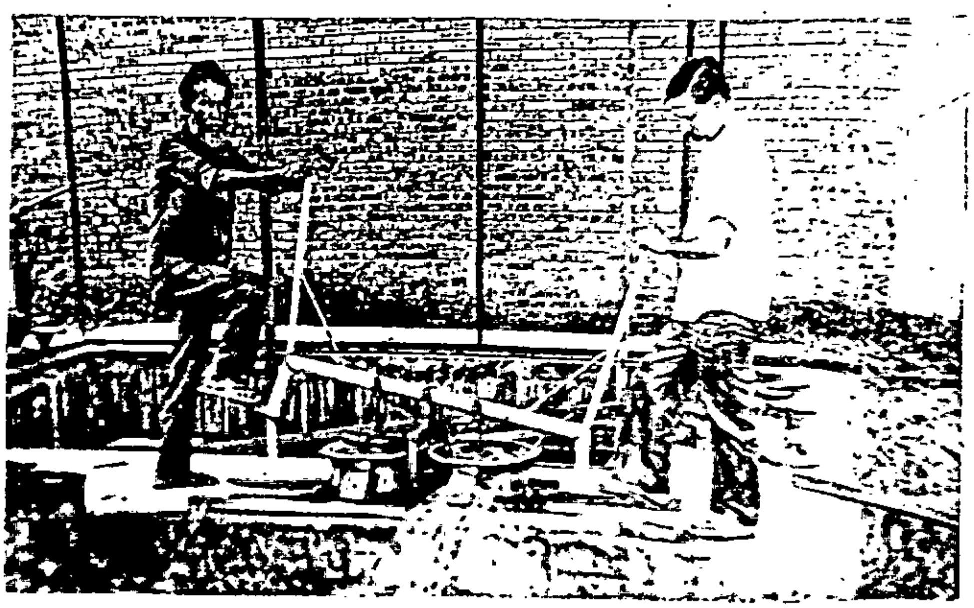

Fig.4 BRRI Diaphragm Pump in Operation

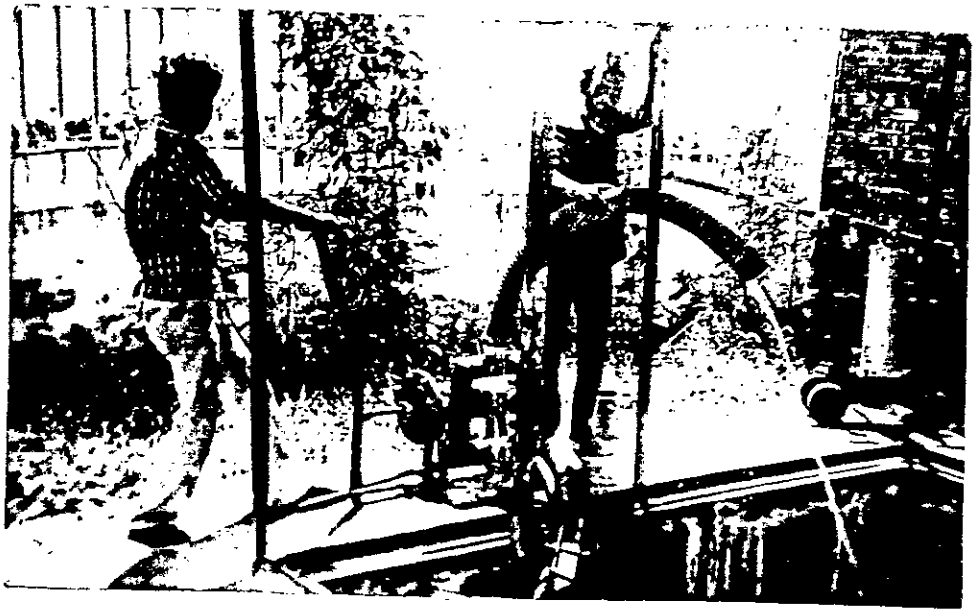

Fig.5 M.L.K. Pump in Operation

Fig.6 Hand Pump in Operation

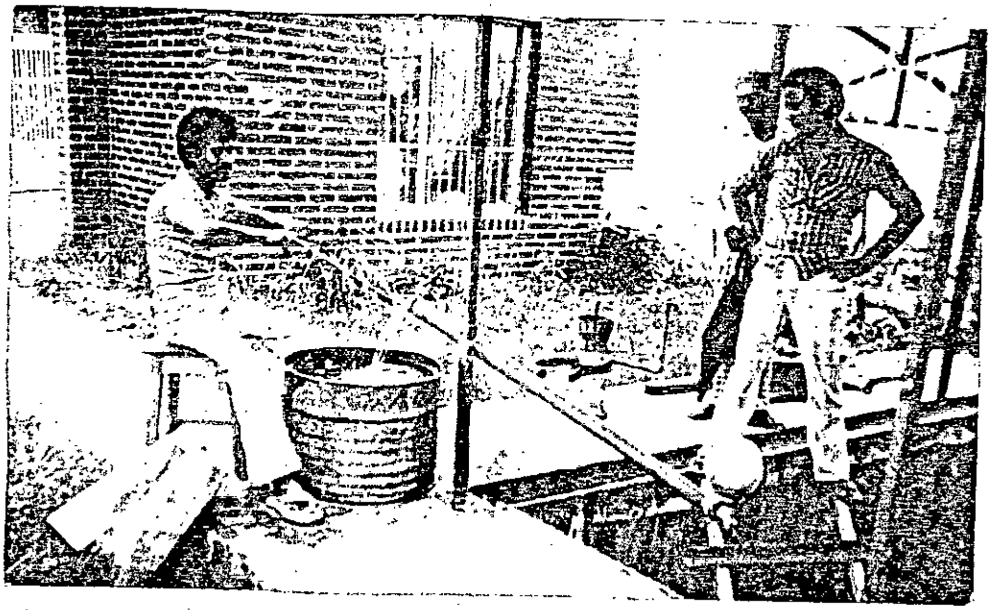

Fig.7 Rower Pump in Operation

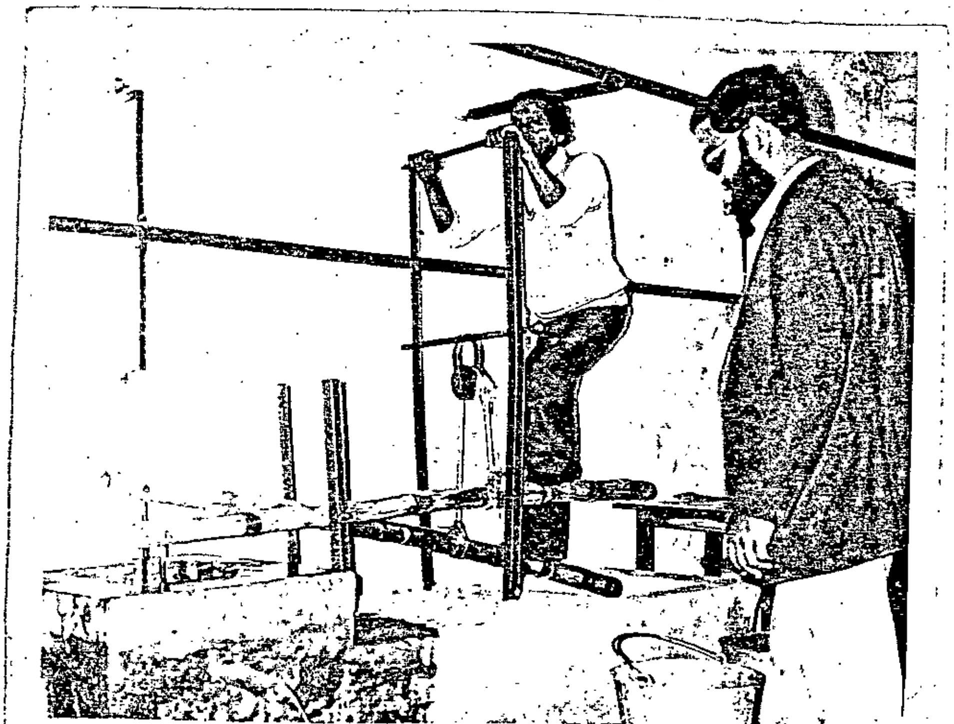

Fig.8 Twin Treadle Pump in Operation

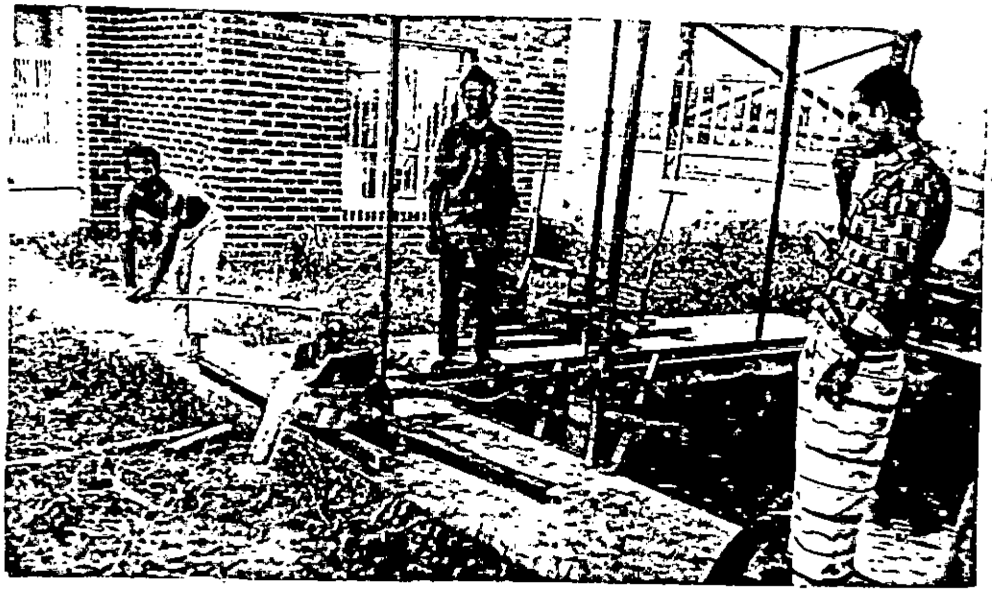

Fig.9 One Man Operated Diaphragm Pump in Operation

Fig.10 Two Men Operated Gardening Pump in Operation

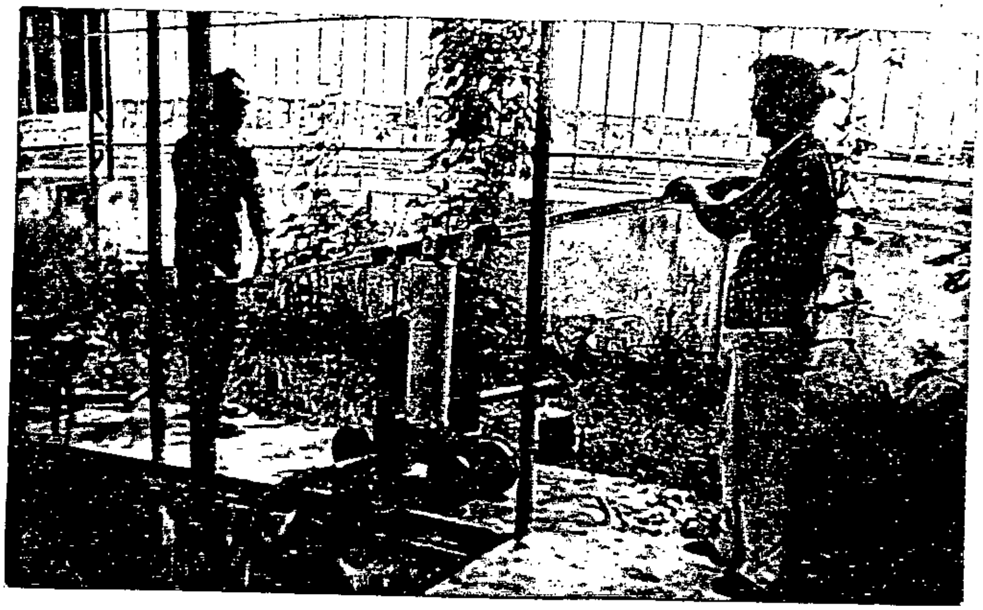

Fig.11 Two Cylinder Reciprocating Pump in Operation

3.2.2 Pump Tests

Laboratory tests were conducted on One Man Operated Diaphram pump, Two Men Operated Gardening pump, Two Cylinder Reciprocating pump and Rower pump at the BRRI Engineering division workshop, Joydebpur, Dhaka.

A tank was used as the source of water supply. Pressure regulator was used to vary the suction head. The inlet of the pressure regulator was immerged into the water and outlet was connected to the inlet of the water lifting devices. Water enters into the device through the pressure regulator. The suction head at which water enters into the device was indicated by the vacuum gauge connected just below the outlet of the pressure regulator. A brass rod connected with a plate, fitted with inlet valve of the regulator extended out through the top of the regulator. Different weights were placed on the brass rod to maintain different suction pressures. The devices were operated by the human energy and time was counted to fill a drum of known volume at each suction head. From the recorded time and volume of the drum discharge at a particular suction head was calculated. Three readings were taken at each suction head. The tests were conducted at four different suction heads. The test results are also included in Table 10 to 13, Appendix-A.

3.3 Data Analysis

The pump test data were analysed to develop characteristic curves for each of the study units.

3.3.1 Pumping efficiency

To get the efficiency discharge relationship the pump efficiency has been calculated for each set of the head-discharge data using the equation.

$$E = \frac{Q\,H}{76\ \ IHP} \times 100 \qquad (1)$$

where, E = Pumping efficiency, percent

Q = Discharge in l/sec

H = Pumping head, m

IHP = Input horse power.

Since the devices are operated by human energy the input horse power was determined from the working capacity of a normal operator.

Campbell(6) proposed that the power output of an adequately fed 35 years old European male labour can be expressed as

$$HP = 0.35 - 0.092 \log t \qquad (2)$$

where HP = Power output of the labour, hp

t = Time of operation, min.

The equation is valed for t ranging from 4 **minute to** 8 hours over 8-hour period a man can deliver work at the rate of approximately 0.10 hp.

A man of 20 years can produce 15% more and a 60 years old man 20% less useful work than the normal. In this study it was assumed that, on average an operator can generate power at the rate of 0.10 hp over 8-hour period (e.g. IHP = 0.10 hp). Although Bangladeshi labour cannot produce energy equal to an European labour. As 20 years labour can produce 15% more energy than 35 years old labour. So it is assumed that 20 years Bangladeshi labour can produce energy equal to 35 years of Europpean labour. As the same value used in all the devices for comparison, the result does not affected by the value used as input horse power.

3.3.2 Economic Appraisal

An economic analysis was conducted to determine the cost effectiveness of each unit. The criteria used in the analysis was benefit-cost ratio defined as

$$\text{Benefit-Cost ratio} = \frac{\text{Annual benefit from irrigation}}{\text{Annual cost to won and operate the unit.}}$$

Since Boro rice can not be grown with out irrigation, the net return from cultivation can be attributed to irrigation benefit. Hence, the annual benefit of using the device was determined by multiplying the command area by per acre net return from boro cultivation.

The maximum possible command area of each system was obtained from the previous study reports. The data on net farm income from boro cultivation in Dhamrai area as obtained by Mirjahan(8) was used in this study.

The annual cost to won and operate the unit can be expressed as

Total Annual Cost = Initial cost x CRF + Annual operating cost + Annual maintenance cost.

where, $CRF = \frac{i(i + 1)^n}{(i + 1)^n - 1}$ (3)

CRF = Capital Recovery factor

i = Discount rate

n = Life of the irrigation device

Data on initial cost and life of the device were collected from the manufacturer. Operating cost was determined from operating hours taking wege rate of Tk. 25.00 per 8 Man hour.

Annual maintenance cost was taken as 10% of the initial cost of the device. A discount rate of 15 was used in the analysis. Operating hours were determined by using the formula,

$qt = 28\ ad$ (4)

where, q = Discharge of the device, l/sec.

t = Time of operation of the device, hrs.

a = Command area of each of the unit, hectre

d = Irrigation required for boro cultivation, cm.

Discharge was taken from the Head-discharge curve drawn corresponding to the maximum efficiency. Data on command area was collected from previous literature.

Irrigation required for boro cultivation was taken from the BRRI report as 22.40 inch (57 cms)(9).

Discharge capacity, possible command area, Initial cost, Life, Annual Maintenance cost and Annual operating cost of each unit are included in Table 14, Appendix-B.

CHAPTER - IV

RESULTS AND DISCUSSIONS

4.1 Performance characteristic of different devices

The characteristic curves of the study units are shown in Figs. 12 to 22.

It is evident from Fig.12 that the discharge of Dhone varied from 7.6 to 3.0 litre/sec as the lift increased from 0.70 to 1.4 m. The efficiency range is 50 to 72%.

Fig. 13 reveals that the discharge of Swing Basket varied from 2.4 to 1.20 l/sec with the change of lift from 0.8 to 1.40 m respectively. The efficiency of the operation varied correspondingly from 12 to 14%. Discharge was found fall rapidly upto 1.10 m then the rate of fall decreased.

The discharge of the Shaduf varied from 0.60 to 1.40 l/sec as head decreased from 6.4 to 3.3 m (Fig. 14).The efficiency varied from 15 to 72% respectively.

The discharge of BRRI Diaphragm pump varied from 5.20 to 2.5 l/sec. When head varied from 0.8 to 3.8 m (Fig.15). The efficiency of operation varies correspondingly from 26.0 to 68%. The slope of the head versus discharge curve is steeper at lower heads than that at higher (above 2.2 m). That mean the discharge reduces rapidly upto 2.44 m, then the rate of fall decreases.

Fig.16 indicates that the discharge of M.L.K.Pump varies from 2.0 to 1.0 l/sec as the head ranges from 3.0 to 5.50 m. The efficiency varies within the range of 75 to 88%.

The discharge of Hand Tubewell varies from 1.20 to 0.90 l/sec as the lift changes from 3.30 to 6.00 m(Fig.17). The efficiency varies from 52 to 68%. The slope of the head discharge curve is very small indicating that variation of discharge with change of lift is small.

The discharge of Rower pump varies from 1.00 to 0.70 l/sec in the range of lift from 2.86 to 7.21 m(Fig.18). The efficiency varies within the range from 37 to 71. The slope of the curve is flatter upto 6.00 m indicating that upto this head the rate of change of discharge with the change of head is smaller than that at higher head. The rate of reduction of discharge decreases beyond this head.

The discharge of Twin Treadle pump varies from 0.4 to 1.20 l/sec as the head decreases from 5.5 to 1.5 m(Fig.19). The efficiency varies 29 to 33 . The rate of fall of discharge with the increase of lift is more or less uniform.

The discharge of One Man Operated Diaphragm Pump varies from 1.50 to 0.70 l/sec with the change of lift from 3.00 to 8.00 m (Fig. 20). The efficiency varies from 60 to 81% within the range of lift. The rate of fall of discharge with the increase of head is more or less uniform.

The discharge of Two Men Operated Gardening pump varied from 1.00 to 0.60 l/sec as the head increases from 3.7 to 7.40 m. The efficiency varies correspondingly in the range from 25 to 35%.(Fig. 21). The nature of the curve is flatter in the lower range upto 6.00 m indicating the rate of decrease of the discharge is low.

Fig. 22 reveals that the discharge of the Two Cylinder Reciprocating pump varied from 0.74 to 0.55 l/sec in the range of lift from 4.00 to 7.5 m. The efficiency varies within the range from 13 to 28%. The slope of the curve is small indicating that the rate of change of discharge with the change of head is low.

4.2 Optimum Operating Condition

Optimum operating condition here means head and discharge corresponding to the maximum efficiency.

The optimum operating condition along with the associated efficiency of each device are shown in the Table-1.

The discharge corresponding to the maximum efficiency was determined from the plotted discharge and efficiency Vs. Head Curves.

Peak point of the Efficiency Vs. Head Curve is the maximum Efficiency. From this efficiency corresponding head was determined and corresponding to this head the discharge Vs. Head Curves of discharge was determined and this discharge is the discharge at optimum operating condition.

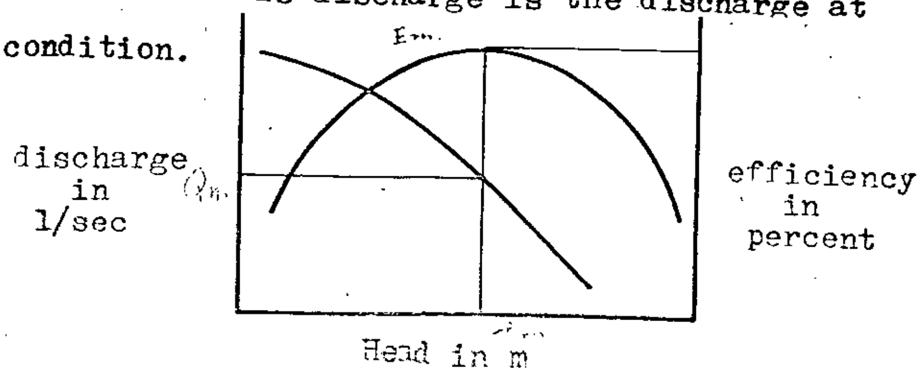

Table - 1

Optimum Operating Condition of the Study Devices

Name of the Devices	Head in m	Discharge in l/sec	Associated maximum efficiency in %
1. Dhone	1.00	5.10	72
2. Swing Basket	1.20	1.50	14
3. Shaduf	4.60	1.20	72
4. BRRI Diaphram pump	3.20	2.80	68
5. M.L.K. Pump	4.00	1.70	88
6. Hand Tubewell	5.00	0.90	67
7. Rower Pump	6.00	0.80	71
8. Twin-Treadle Pump	4.00	0.60	33
9. One Man Operated diaphram pump	5.60	1.00	81
10. Two Men Operated gardening pump	6.20	0.80	35
11. Two Cylinder Reciprocating pump	7.00	0.50	28

The possible devices within the lift range of 0-1.5 m are Dhone and Swing Basket. Dhone has the discharge capacity of 5.10 l/sec at the head of 1.00 m corresponding to the maximum efficiency of 72% where as Swing Basket has the discharge of 1.50 l/sec at the head of 1.20 m inrespect to the maximum efficiency of 14% only. In this head range Dhone was found to be the most efficient Device having discharge capacity 3 times and efficiency 5 times the corresponding values for Swing Basket. This is because higher input energy is applied in supporting and lifting water by Swing Basket.

The possible devices within the lift range of 1.5 to 4.5 m are BRRI Diaphragm pump, M.L.K Pump and Twin Treadle pump. In this range M.L.K pump is the most efficient device. The discharge of this device is 1.70 l/sec at the head of 4.00 m corresponding to the maximum efficiency of 88%. BRRI diaphragm pump follows M.L.K pump having the discharge and head corresponding to this efficiency as 2.80 l/sec and 3.20 m respectively to the maximum efficiency of 68.0%.

The possible devices within the range of lift from 4.50 to 7.5 m are Shaduf, Hand Tubewell, Rower Pump, One Man Operated Diaghragm pump, Two Men Operated, Gardening pump and Two Cylinder Reciprocating Pump. The most efficient pump within this range is one Man Operated diaphragm pump having the maximum efficiency of 81.0% at the head of 5.6 m and the discharge at this head is 1.00 l/s.

This was followed, in the order by Shaduf, Rower Pump, Hand Tubewell, Two Men Operated Gardening pump and Two Cylinder Reciprocating pump having the maximum efficiency of 72, 71, 67, 35 and 28 % respectively.

4.3 Economic Analysis

The results of the economic analysis are given in the following table-2.

Table-2

Benefit to cost ratio of study devices

Name of the Devices	Annual System cost in Tk.	Annual Irrigation benefit in Tk.	Benefit to cost ratio
1. Dhone	1763	21,620	12.26
2. Swing Basket	2458	5,405	2.20
3. Shaduf	834	1,802	2.16
4. BRRI Diaphram pump	3234	10,810	3.34
5. M.L.K. Pump	2625	8,108	3.09
6. Hand Tubewell	1380	2,703	1.96
7. Rower Pump	1715	2,703	1.58
8. Twin Treadle pump	2361	3,603	1.53
9. One Man Operated Diaphram pump	1565	2,703	1.73
10. Two Men Operated Gardening pump	2775	2,703	0.97
11. Two Cylinder Reciprocating pump	3000	1,802	0.60

In the light of the economic analysis the following are abserveable.

The Benefit to cost ratio of Dhone was the highest (12.26) but it can be used only upto a head of 1.5 m. Lifting of water to a higher head by Dhone can be possible by increasing the number of stages. But economic gains might be decreased if we increase the number of stages. Morevoer the device can be used only to divert surface water. In the same range of head Swing Basket was found to give benefit-to cost ratio of only 2.20.

The benefit to cost ratio of the devices within head range of 1.5 to 4.5 m varied from 1.53 to 3.34. The BRRI diaphram pump was found to give the highest benefit to cost ratio. This might be because of its high discharge and command area compared to the other two device.

In the head range of 4.5 to 7.5 m Shaduf was found to give the highest benefit to cost ratio followed by Hand Tubewell, one man operated diaphram pump and Rower pump.

Two Men Operated Gradening pump and Two Cylinder Reciprocating pump were economically infeasible to use.

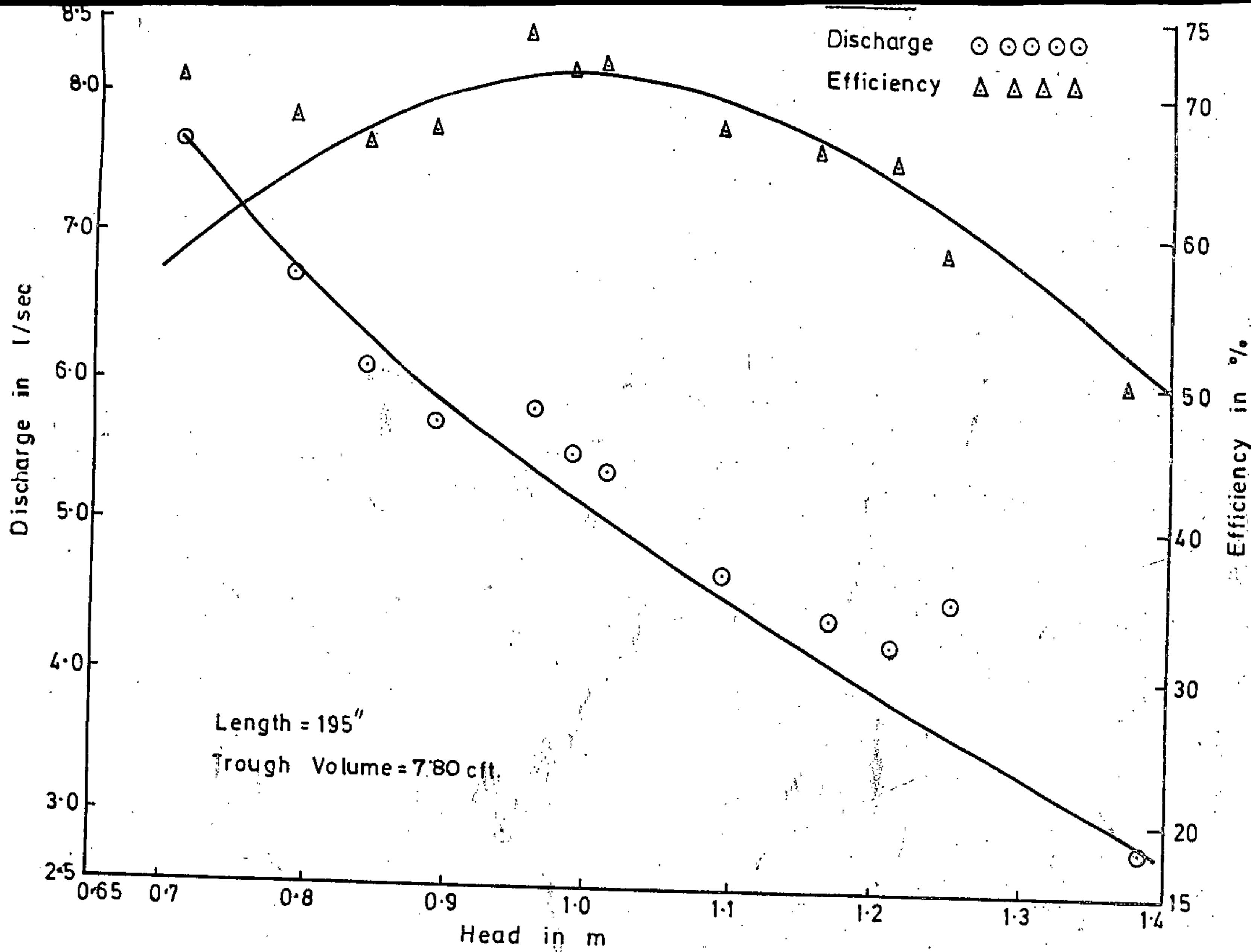

FIG. 12 DISCHARGE AND EFFICIENCY VS. HEAD OF DHONE

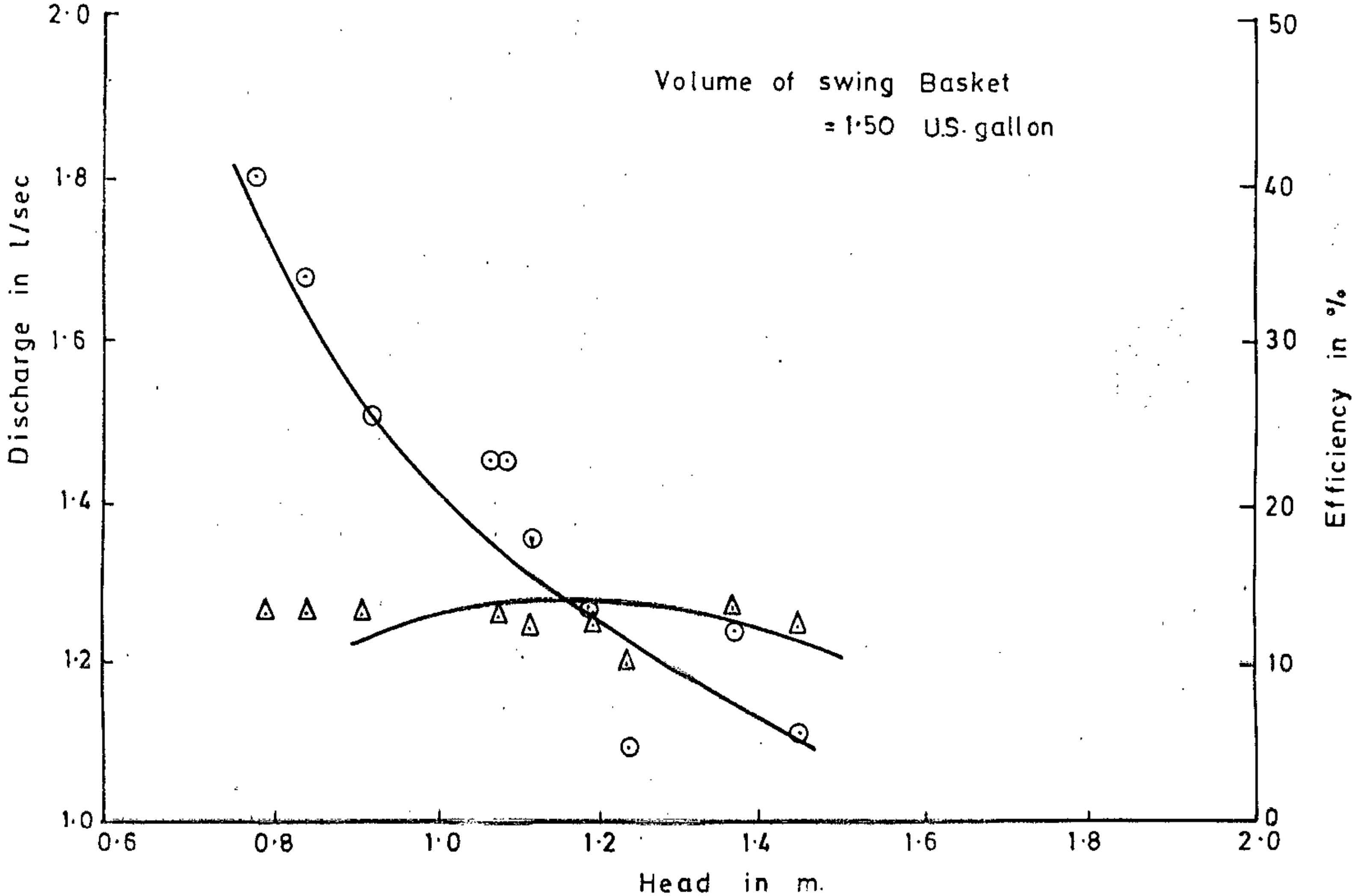

FIG. 13 DISCHARGE AND EFFICENCY VS. HEAD OF SWING BASKET

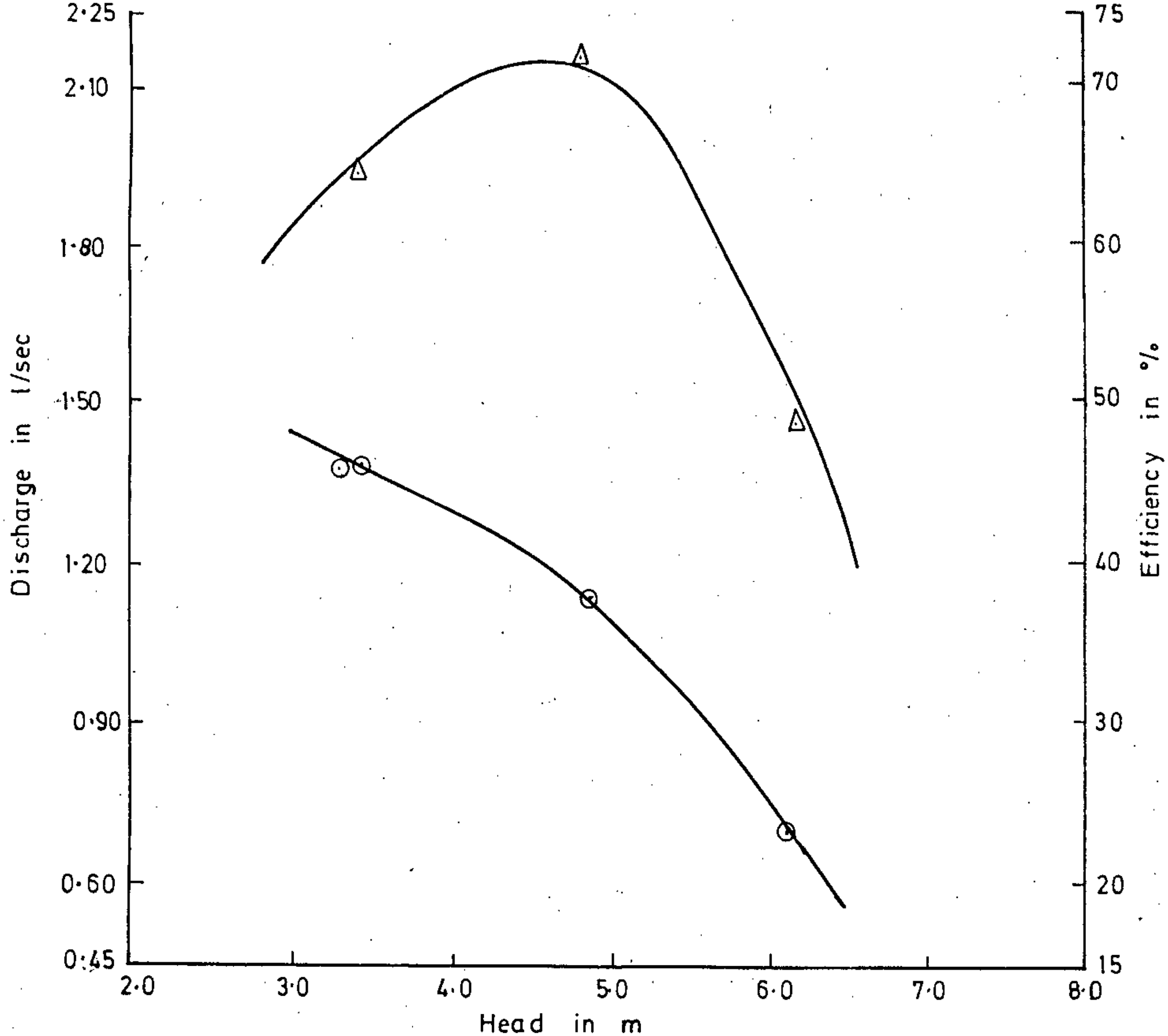

FIG. 14 HEAD VS. DISCHARGE AND HEAD VS. EFFICIENCY OF SHADUF

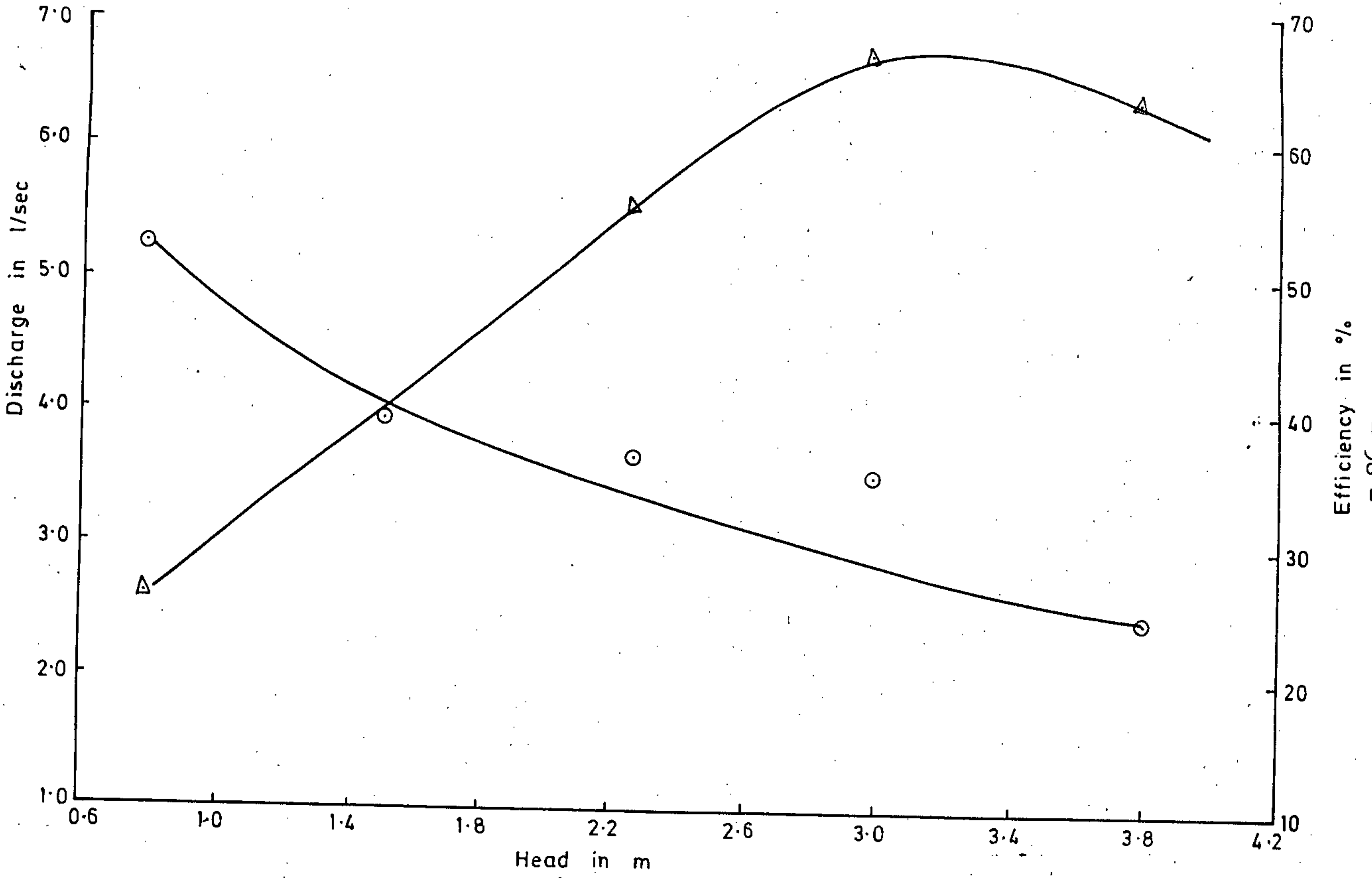

FIG. 15 HEAD VS DISCHARGE AND EFFICIENCY OF BRRI DIAPHRAM PUMP

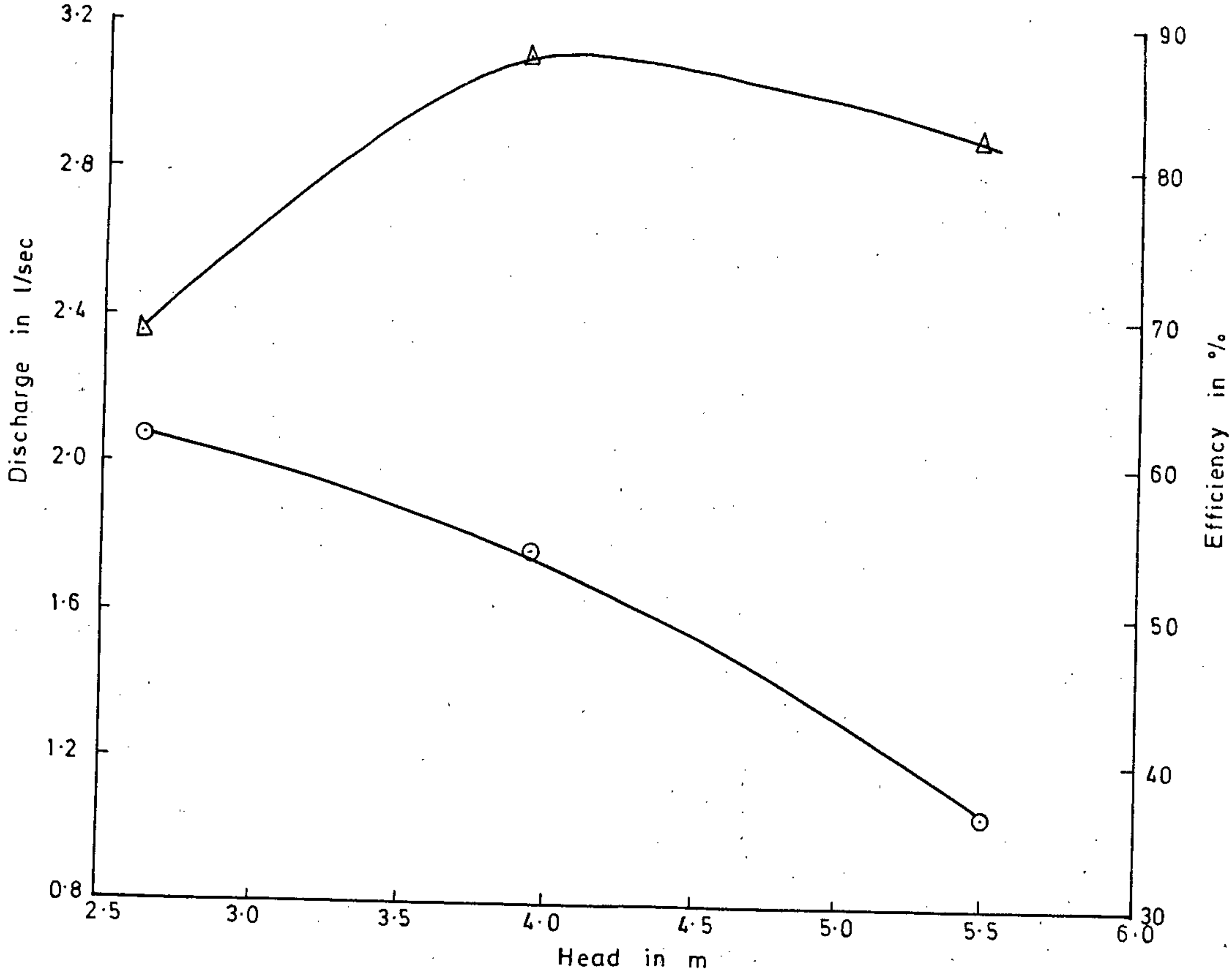

FIG. 16 DISCHARGE VS. HEAD AND EFFICIENCY VS. HEAD OF M. L.K. PUMP

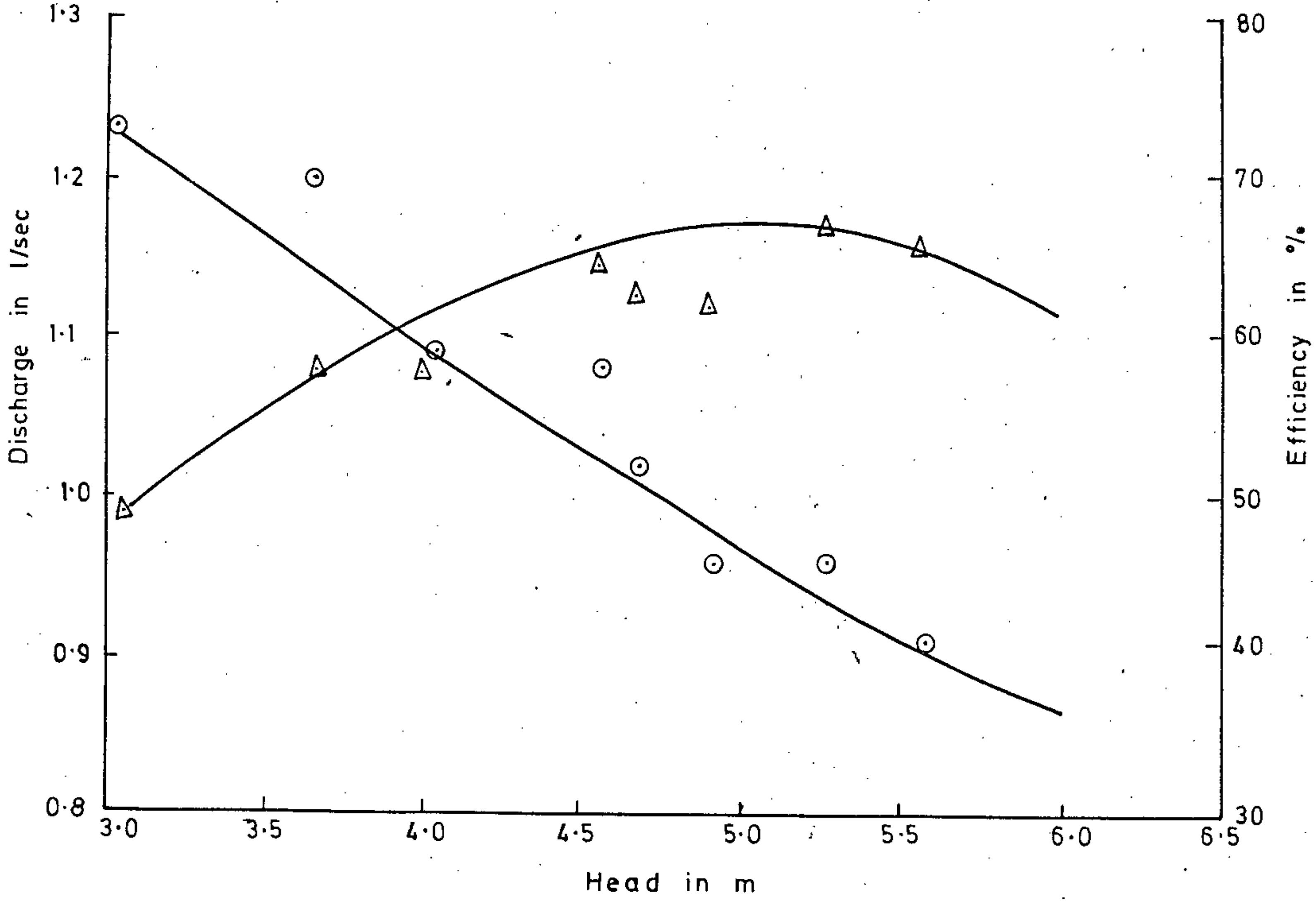

FIG. 17 DISCHARGE AND EFFICIENCY VS. HEAD OF HAND TUBEWELL

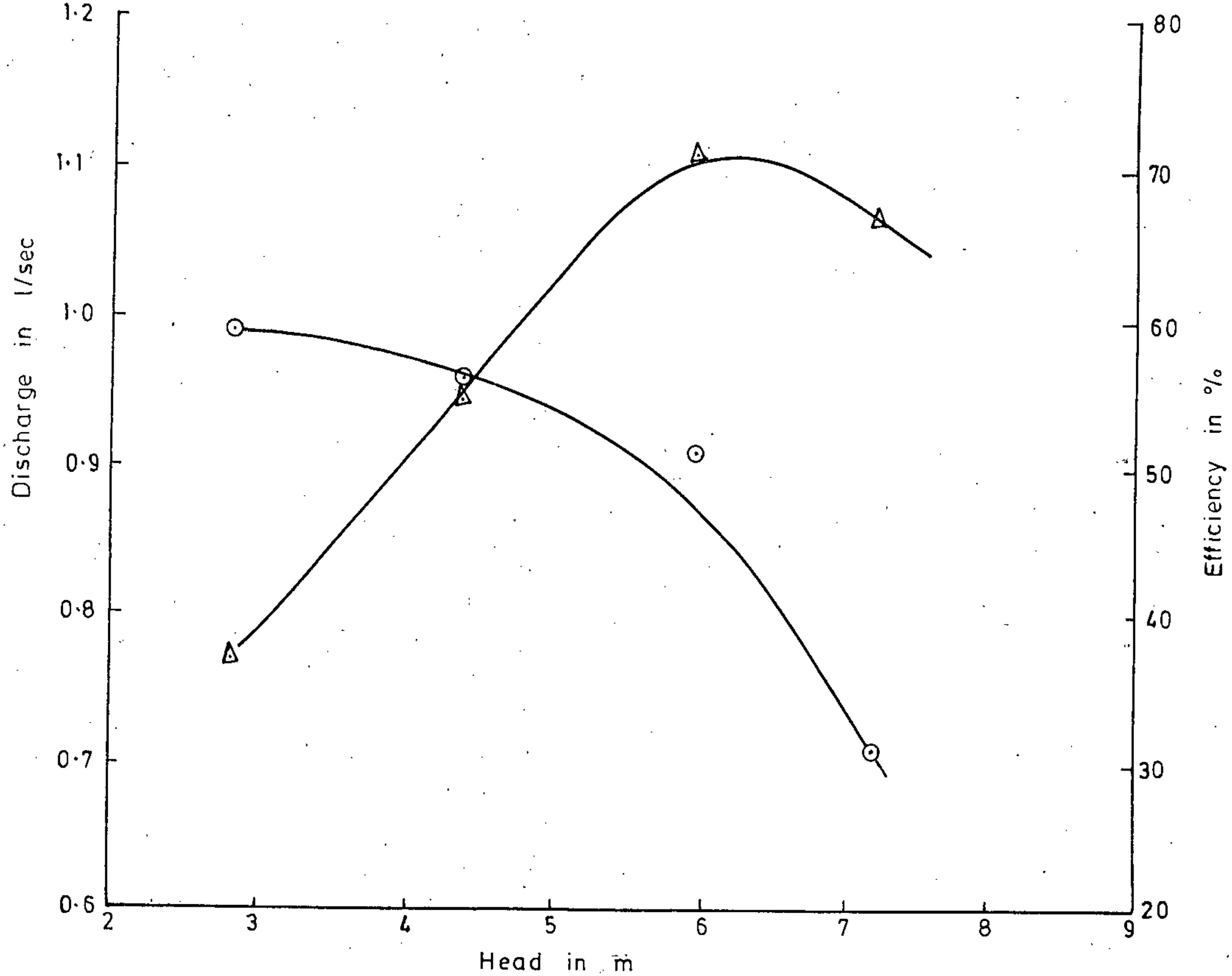

FIG. 18 DISCHARGE AND EFFICIENCY VS. HEAD OF ROWER PUMP

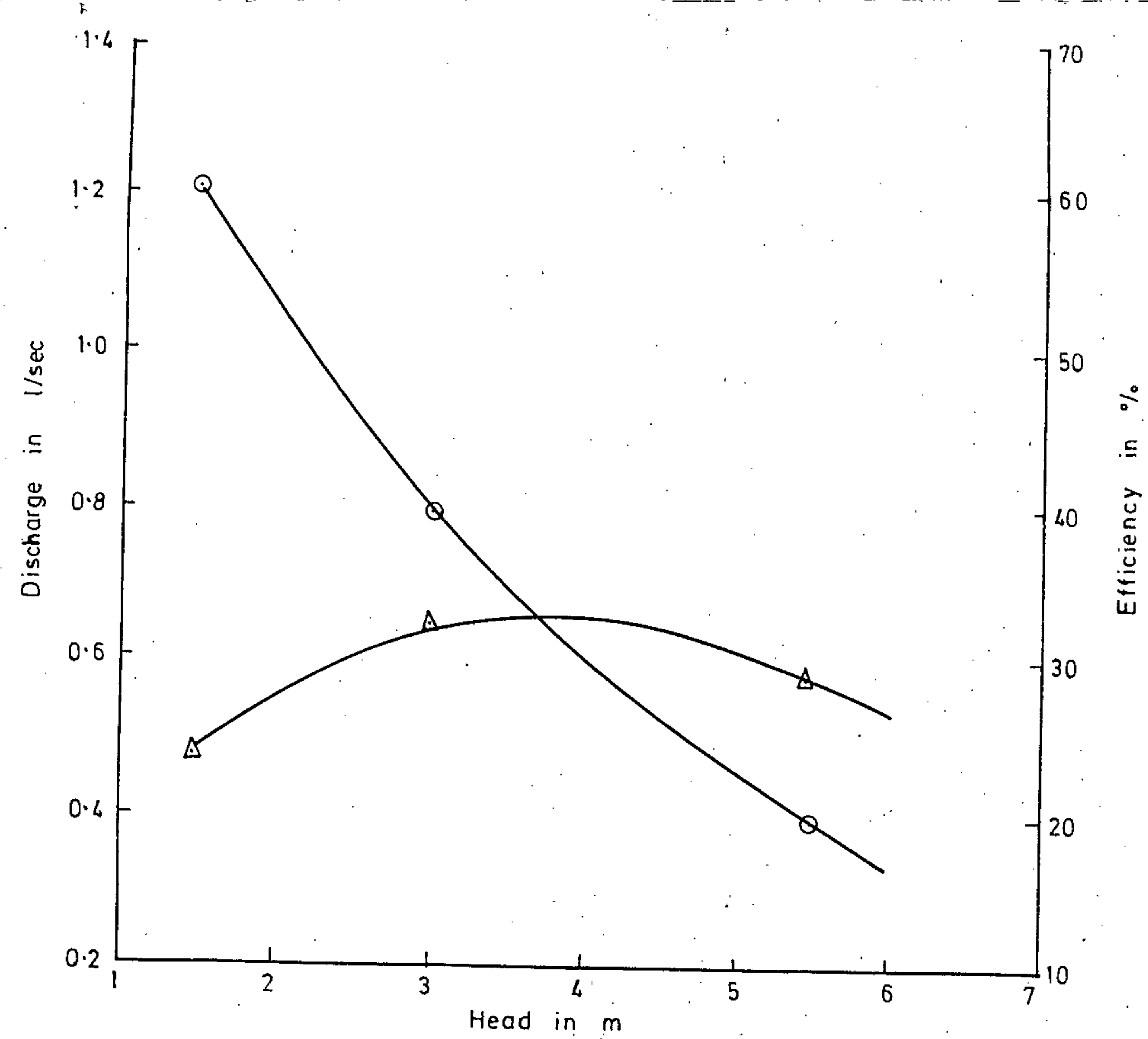

FIG. 19 DISCHARGE AND EFFICIENCY VS. HEAD OF TWIN TREADLE PUMP

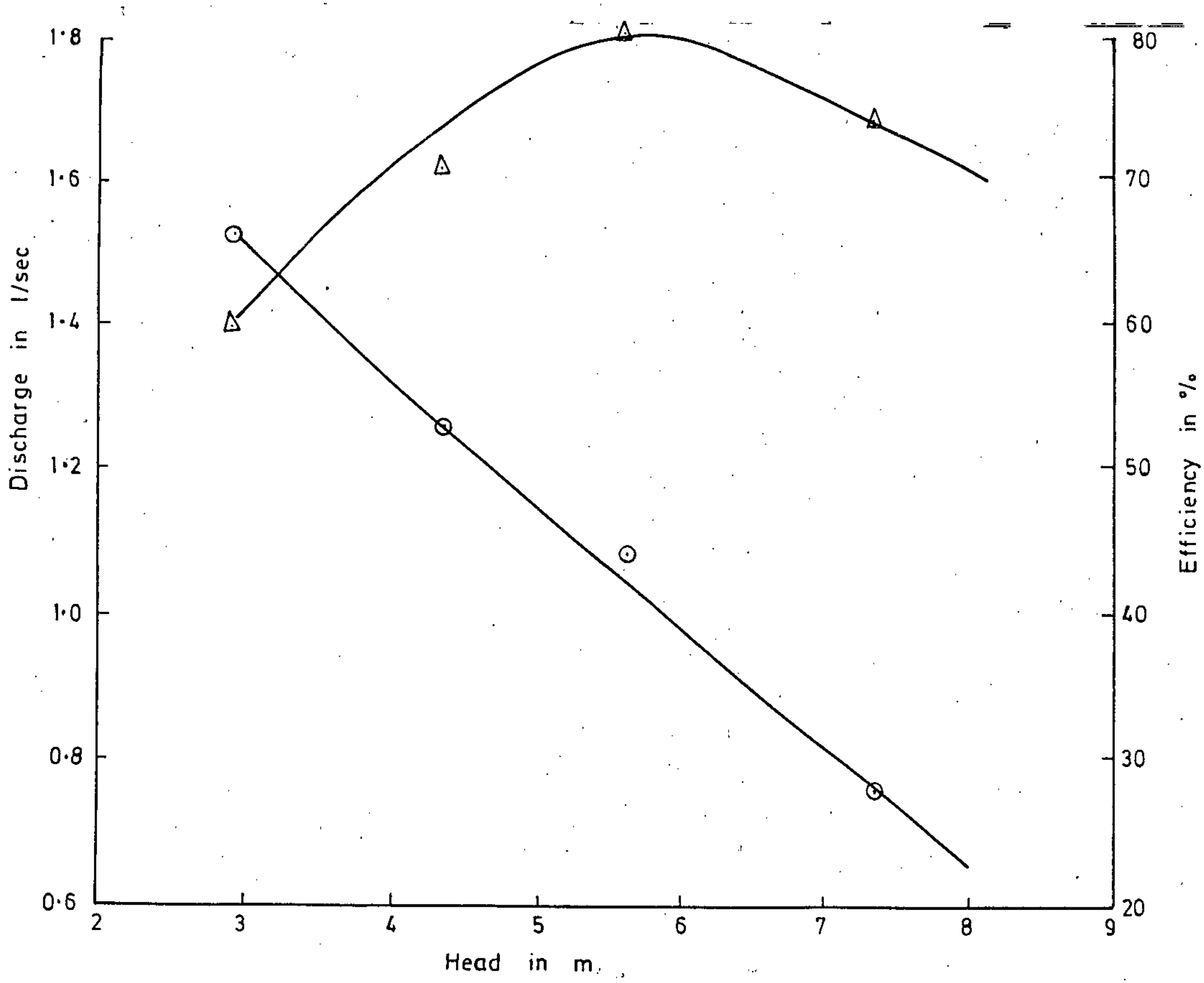

FIG. 20 DISCHARGE AND EFFICIENCY VS. HEAD OF ONE MAN OPERATED DIAPHRAM PUMP

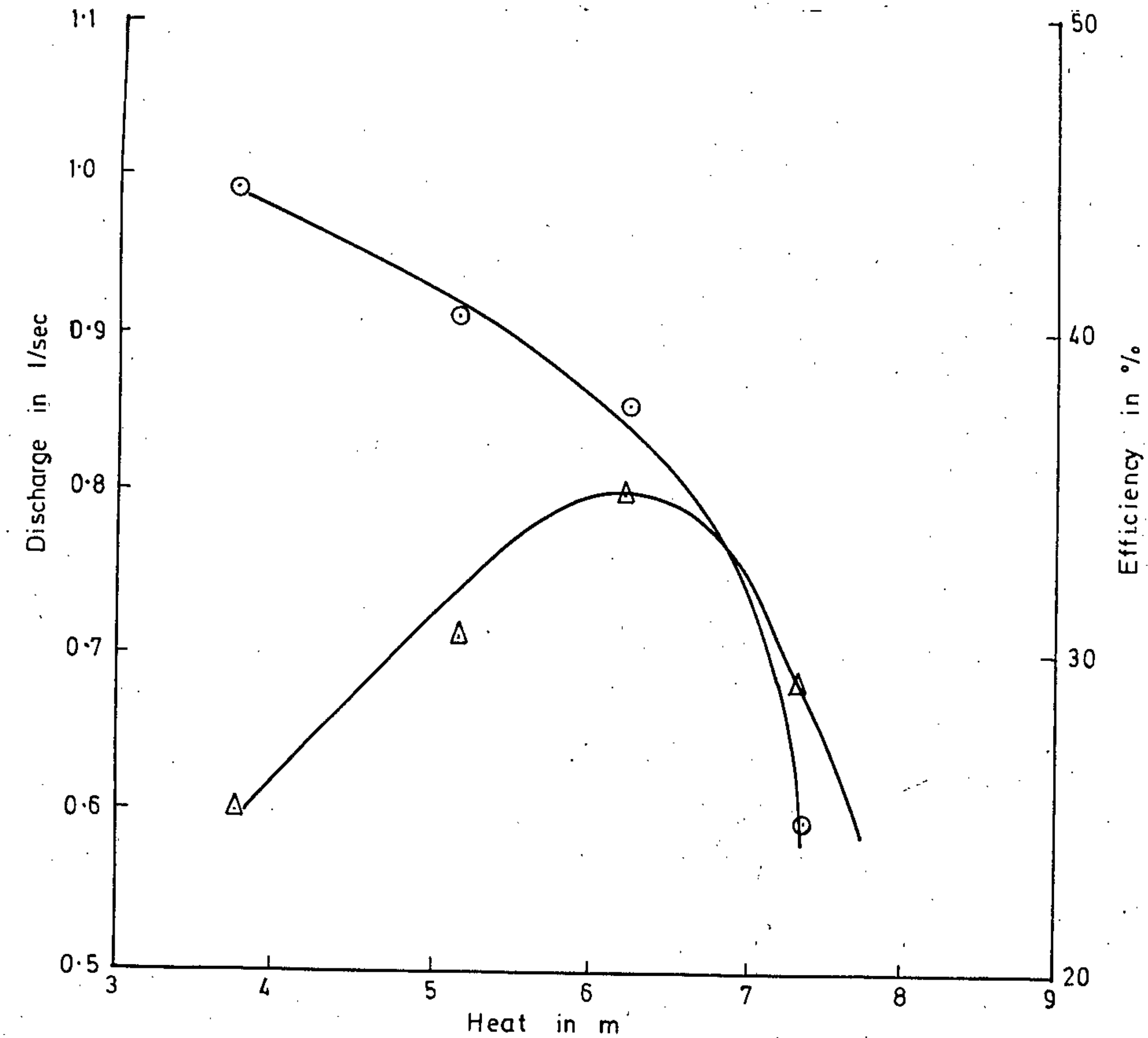

FIG. 21 DISCHARGE AND EFFICIENCY VS HEAD OF TWO MEN OPERATED GARDENING PUMP

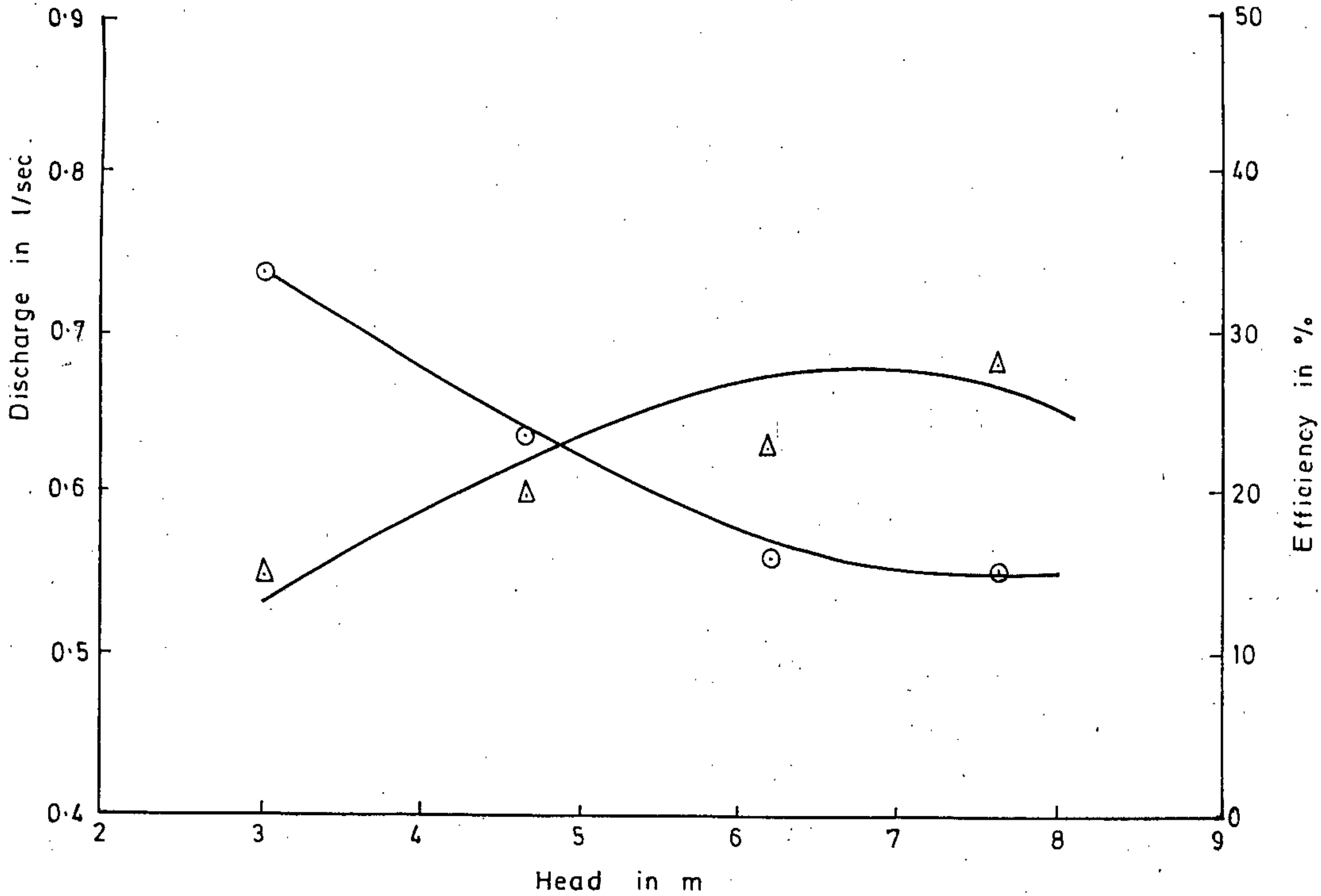

FIG. 22 TWO-CYLINDER RECIPROCATING PUMP DISCHARGE AND EFFICIENCY VS. HEAD

CHAPTER - V

CONCLUSION AND RECOMMENDATION

In the light of the comparison of pumping efficiency, economic analysis and discharge at the optimum operating condition the following conclusion may be drawn.

Within 0-1.5 m lifting height 'Dhone' irrigation device found to the most efficient and economically attractive. Swing basket needs greater operational energy because it requires two men to lift the water. All the weight of water lifted is carried by the operators themselves. Both efficiency and benefit to cost ratio were found to be very low. Hence it is strongly discouraged.

Upto 3.0 m lift BRRI Diaphram pump was found to be the best device in term of rated capacity, efficiency and economy. It should be noted that BRRI Diaphram pump can efficiently be used within the head range of 1.5 to 3.0 m. For higher head 3.0 to 4.5 m M.L.K. Pump can be used.

When lifting of water is required within the range of 4.5 to 5.5 m Hand Tubewell was found to be the most efficient device but the benefit cost ratio of Hand Tubewell was found to be slightly less than that of Shaduf.

Upto the lift of 6.00 m. One Man Operated Diaphram pump was found to be the best device in term of rated capacity efficiency and economy.

Rower pump was found only the economically feasible device within the head range of 6.0 to 7.5 m. The other devices within this head range are not found to be economically viable.

Most of the data used in the economic analysis were obtained from the literature and judicious assumptions. Hence, further verification of the data an up dating of conclusions are necessary. In this study the pump tests were confined only at few selected heads. Further tests covering the whole range is recommended.

BIBLIOGRAPHY

1. Ahmed K.U., 'Study of Performance Characteristics of Some Manual Methods of Irrigation', M.Sc.Engg. Thesis, Water Resources Engineering Department, BUET, Dhaka, 1982.

2. Mostafa M.G., 'Water Lifting Devices in Developing Countries', M.Engg. Special Studies, AIT, Bangkok, Thailand, 1981.

3. Khan, H.R., 'FAO Workshop on Water Lifting Devices in Asia and the near East', Bangkok, Thailand, 1979.

4. Gani M.A., Islam Taufiqul, Khondokar Humayun Kabir,' Collection of different types of Manually operated pumps available in the country and Evaluation of their performance in order to select the best available design to carry further modification if necessary to improve performance' AG.Engg. Res.Report No.7, Bangladesh Rice Research Institute, Joydebpur Dhaka, 1983.

5. Islam M.S., and Majed M.A.,'Comparison of performances of Different types of manual pumps', Technical bulletin No.AED/80/1 Bangladesh Agricultural Research Institute, Joydebpur,Dhaka, 1980.

6. Champbell J.K., 'Report of Three week study on Bangladesh for the cornell/USAID Water Management Synthesis 11 Project', 1983.

7. Khondaker Azharul Haq, et al., 'BRRI Internal Review Report, Bangladesh Rice Research Institute, Joydebpur, Dhaka, 1984.

8. Miah M.M., 'Improvement of Deep Tubewell Irrigation Project Performance in Bangladesh', dissertation presented to Utah State University, at Logan, Utah in 1984, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

9. Khondokar Azharul Haq, et al., 'Irrigation and Water Managment Report, BRRI, Joydebpur, Dhaka.

10. Klassen, 'The Rower Pump' Menonite Central Committee, Bangladesh.

11. Bangladesh Bureau of Statistics, Dhaka, Bangladesh.

Appendix - A

The Head versus discharge data of Dhone swing Basket, Shaduf, BRRI dimphaum pump, Hand Tubewell, M.L.K. Pump, and Twin Treadle Pump as collected from literature source are given in the table 3 to 9. That of Rower pump, one man Cperated Diaphram pump. Two Men Operated Gardening pump. Two cylinder Reciprocating pump as obtained from pump test are also given in the table 10-13.

Table - 3

Performance of 195 inch length Dhone (1)

Lifting height	Average Discharge				Efficiency in %
in m	in ft or inch	in cusec	in l/sec	gpm(U.S)	$EP = \frac{QwH}{550(IHP)}$
0.71	28	0.269	7.62	120.66	71
0.79	31	0.231	6.54	103.83	68
0.84	33	0.213	6.03	95.97	66
0.89	35	0.202	5.72	90.85	67
0.96	38	0.207	5.86	93.02	74
0.99	39	0.196	5.55	87.97	72
1.02	40	0.191	5.41	85.86	72
1.09	43	0.164	4.64	73.66	66
1.17	46	0.153	4.33	68.75	66
1.22	48	0.143	4.05	64.40	65
1.27	50	0.124	3.51	55.56	59
1.37	54	0.098	2.77	44.20	50

Table - 4

Performance of swing basket 1)

Lifting height		Average discharge capacity			Efficiency in %
in ft or inch	in m	cusec	gpm(U.S)	l/sec	
42	1.07	0.067	30.08	1.90	13
44	1.12	0.060	26.24	1.70	12
47	1.19	0.053	23.80	1.50	12
31	0.79	0.092	41.31	2.60	13
33	0.64	0.083	37.27	2.35	13
36	0.91	0.074	33.25	2.09	13
49	1.24	0.042	18.86	1.19	10
54	1.36	0.052	23.35	1.47	13
57	1.45	0.044	19.76	1.25	12

Table - 5

Performance characteristic of shaduf(2,6)

Lifting height		Average discharge			Efficiency in %
in inch ft	in m	in cusec	in gpm(U.S)	in l/sec	
12	3.66	0.048	22	1.36	65
16	4.88	0.040	18	1.13	72
20	6.10	0.022	10	0.63	49

Table - 6

Performance characteristic of BRRI Diaphram Pump(7)

Lifting height		Average discharge			Efficiency in %
in ft	in m	in gpm(U.S)	in cusec	in l/sec	
2.55	0.78	82.88	0.18	5.23	26
4.91	1.50	62.44	0.14	3.94	39
7.48	2.28	57.68	0.13	3.64	55
3.64	3.00	55.66	0.12	3.51	67
12.46	3.80	38.46	0.09	2.43	64

Table-7

Performance characteristic of M.I.K. Pump(7)

Lifting height		Average discharge			Efficiency in %
in ft	in m	in gpm(U.S)	in cuse	in l/sec	
9.69	2.65	33.00	0.07	2.08	69
12.95	3.95	27.70	0.06	1.75	88,
18.04	5.50	16.80	0.04	1.06	82

Table - 8

Performance characteristic of a Hand Tubewell (New) (1)

Lifting height		Average discharge			Effiency in %
in inch	in m	in gpm(U.S.)	in cusec	in l/sec	
120.00	3.05	19.98	0.0433	1.23	49
144.96	3.68	19.43	0.0424	1.20	58
159.00	4:04	18.34	0.0386	1.09	58.
180.00	4.57	17.19	0.0383	1.08	65
186.00	4.72	16.06	0.0539	1.02	63
194.04	4.93	15.67	0.0339	0.96	62
209.04	5.31	14.86	0.0340	0.96	67
219.00	5.56	14.45	0.0322	0.91	67
219.00	5.56	15.44	0.0344	0.97	66

Table - 9

Performance characteristic of Twin Treadle Pump(6) .

Lifting height		Average discharge			Efficiency in %
in ft	in m	in gpm(U.S)	in cusec	in l/sec	
5	1.52	18.85	0.042	1.2	24
10	3.05	12.57	0.028	0.8	32
18	2.44	6.28	0.014	0.4	29

Table - 10

Performance characteristics of Rower Pump

Lifting height		Average discharge			Efficiency in %
in inch	in m	in gpm(U.S)	in cusec	in l/sec	
112.50	2.86	15.72	0.035	0.99	37
171.48	4.35	15.27	0.034	0.96	55
235.68	5.99	14.37	0.032	0.91	71
283.92	7.21	11.23	0.025	0.71	67

Table - 11

Performance characteristics of one man operated diaphram pump

Lifting height		Average discharge			Efficiency in %
in ft	in m	in gpm(U.S)	in cusec	in l/sec	
9.82	2.99	24.24	0.054	1.53	60
14.29	4.36	19.75	0.044	1.25	71
18.75	5.72	17.06	0.038	1.08	81
24.11	7.35	12.12	0.027	0.76	74

Table - 12

Performance characteristic of Two Men operated gardening pump

Lifting height		Average discharge			Efficiency in %
in ft	in m	in gpm(U.S)	in cusec	in l/sec	
12.5	3.81	15.72	0.035	0.99	25
16.96	5.17	14.37	0.032	0.91	31
20.54	6.26	13.47	0.030	0.85	35
24.11	7.35	9.43	0.021	0.59	29

Table - 13

Performance characteristic of Two Cylinder Reciprocating Pump

Lifting height		Average discharge			Effieiency in %
in ft	in m	in gpm (U.S)	in cusec	in l/sec	
9.82	2.99	11.76	0.0262	0.74	15
15.18	4.63	10.19	0.0227	0.64	20
20.50	6.25	8.89	0.0198	0.56	23
25.00	7.62	8.75	0.0195	0.55	28

Appendix - B

Table - 14

OPerational cost of the study devices

Name of the Devices	Discharge Q in cusec	Command area in acre	Initial cost	Life	Annual maint. cost in % of initial cost	Annual operan. cost
1. Dhone	0.187	4	600/-	4	10	1,500/-
2. Swing Basket	0.0579	1	75/-	2	10	2,400/-
3. Shaduf	0.0356	1/3	250/-	2	10	655/-
4. BRRI Diaphram pump	0.1046	2	1,500/-	5	10	2,675/-
5. M.L.K. Pump	0.0579	1 1/2	2,500/-	6	10	1,800/-
6. Hand Pump	0.0334	1/2	1,000/-	6	10	1,050/-
7. Rower pump	0.0316	1/2	8,000/-	2	10	1,100/-
8. Twin Treadle Pump	0.0233	2/3	500/-	2	10	2,003/-
9. One Man Operated diaphram pump	0.0345	1/2	1,800/-	7	10	1,025/-
10. Two Men Operated gardening pump	0.030	1/2	1,500/-	7	10	2,325/-
11. Two cylinder Reciprocating pump	0.0194	1/3	2,000/-	7	10	2,400/-

Appendix - C

Table - 15

Growth phase wise water requirement of rice in Boro, 1983

Treatments	Seedling establishment			Tillering stage				Booting to milk stages				Soft dough to harvest	Grand total (cm)
	Water applied (cm)	Rain-fall (cm)	Total (cm)	Water applied (cm)	Rain-fall (cm)	Drained out (cm)	Total (cm)	Water applied (cm)	Rain fall (cm)	Drain-ed out (cm)	Total (cm)		
Continuous standing water (5-7 cm.)	7.41	1.01	8.42	42.00	16.23	-	58.23	39.69	35.30	-	75.0	12.22	154.4
Saturated condition	7.41	1.01	8.42	26.46	16.23	6.13	36.56	10.05	35.30	22.84	22.51	12.82	80.3
Inter-mittent irrigation	7.41	1.01	8.42	24.00	16.23	-	40.23	15.72	35.30	-	51.02	12.82	112.4