DEVELOPMENT OF TECHNOLOGY FOR UTILISATION OF HARVESTED RAIN WATER THROUGH MICRO-IRRIGATION SYSTEM

BY

Kshyana Prava Samal

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)
IN
SOIL AND WATER CONSERVATION ENGINEERING

Department of Soil and Water Conservation Engineering
COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
Orissa University of Agriculture and Technology
BHUBANESWAR
SEPTEMBER, 2002.

DEVELOPMENT OF TECHNOLOGY FOR UTILISATION OF HARVESTED RAIN WATER THROUGH MICRO IRRIGATION SYSTEM

By

Kshyana Prava Samal

A THESIS SUBMITTED TO THE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,
BHUBANESWAR

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)
IN
SOIL AND WATER CONSERVATION ENGINEERING
2002

Approved by the advisory committee

(DR. S. Swain)
Dean, C.A.E.T.

Chairman : (Dr. K.N. Sharma)

Member-1 : (Dr. N.N. Sahu)

Member-2 : (Dr. J.C. Muduli)

External Examiner

DEDICATED

TO

MY BELOVED PARENTS

Dr. K.N. Sharma,
Associate Professor,
Department of Soil and Water Conservation Engineering
And Principal Investigator of NATP, (RRPS-7)
College of Agricultural Engineering and Technology,
O.U.A.T., Bhubaneswar

CERTIFICATE

This is to certify that the thesis entitled "**DEVELOPMENT OF TECHNOLOGY FOR UTILISATION OF HARVESTED RAIN WATER THROUGH MICRO-IRRIGATION SYSTEM**" submitted in partial fulfillment of the requirements for the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in Soil and Water Conservation Engineering** of the Orissa University of Agriculture and Technology is a faithful record to bonafide research work carried out by **Mrs. Kshyana Prava Samal** under my guidance and supervision during the academic session 2000-2002. No part of the thesis has been submitted for any other Degree or Diploma.

The assistance and help received as well as sources of information availed during the course of investigation have been duly acknowledged

24.9.2002

Bhubaneswar

Dated : 24th September, 2002 **(Dr. K.N. Sharma)**

ACKNOWLEDGEMENTS

The author avails her unique opportunity and proud privilege to epitomize her deepest sense of gratitude and indebtedness to Dr. K.N. Sharma, Associate Professor, Department of Soil and Water Conservation Engineering and Principal Investigator of NAIP (RRPS-7) for his scholastic guidance, constant supervision, ceaseless encouragement, renovative ideas and persistent endeavour throughout the period of investigation. His inspiring assistance, laconic reciprocation and affectionate care, inspite of his engagements prompted her to complete her work and to prepare the manuscript smoothly and successfully.

The author is grateful to Dr. N.N. Sahu, Head, department of Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, O.U.A.T, for his valuable suggestions, encouragement, throughout the period of investigation.

The author is highly obliged to Director, WTCER, Dr. H.N. Verma, for his permission to utilize workshop and laboratory facilities for completion of the project.

The author is highly obliged to Dr. R.C. Srivastava, Principal Scientist, WTCER, Bhubaneswar for his sustained interest, constant supervision, guidance, encouragement, painstaking efforts and providing all laboratory facilities for completion of the work.

The author also express her profound gratitude and reverence to Dr. S. Swain, Dean, College of Agricultural Engineering and Technology, O.U.A.T., for his constant inspiration till the completion of the work.

The author is grateful to Dr. S.D. Sharma, Dean., P.G for his inspiration and good suggestions during the period of work

The author owes her obligation to Dr. J.C. Muduli, Director, College of Basic Sciences and Humanities, O.U.A.T, Bhubaneswar for his timely help during research work.

The author is highly indebted to Shri S. Mohanty, Scientist (SS), WTCER for his interest, constant encouragement and proper guidance to carry out the research work

The author extends her special indebtedness to Scientists Miss M. Das, Smt. R.R. Sethi, Dr. B.K. James, Dr. R. K. Mohanty, Er. D. U. Patil for their help during the course of my research work

The author expresses her profound gratitude to her reverend teachers Shri S. C. Nayak, Shri A.P. Sahoo, Shri J.C. Paul and Sri Sanjay Dash for their timely help and valuable advice. She is also indebted to one and all in the department of SWCE and in the College of Agricultural Engineering and Technology, OUAT.

The author expresses her deep appreciation for the help and co-operation rendered to her by her seniors and friends, Shri N. Mohanty, Shri G.C. Dhal, Shri P. Sethi, Shri A. Routray, Shri S. Pattnaik, Shri. S. Swain, Shri S. Sethi, Smt. D. Sahoo, Miss. R. Pati, Miss B. Dhal Samant, Miss. D. Kar, Miss A. Gupta, Miss, P. Mishra and Shri P. Jena.

The author expresses her heartfelt thanks to all her M. Tech classmates, C.A.E.T., for their help and co-operation during the research work.

The author is highly thankful to one and all members of Hydraulics Lab and Workshop members of WTCER for their constant help.

Thanks are due to Hi-Tech Computer Centre, Siripur for typing the manuscript and preparing the thesis report.

At the nib, but not the neaptide, the author bows down her head before her adorable parents, uncle, aunty, brothers and sisters, whose blissful blessings unfathomable love, scrupulous dedication and incessant inspirations have made her so today. Their sincere love, affection and blessings, always stand as able company in every walks of her life.

The last but not the least, I record my profound reverence to my husband whose constant inspiration has made me to complete the work easily and successfully.

The author lastly prays from the deepest core of her heart to LORD SIVA for his blessings for successful completion of her research work.

Bhubaneswar.

Dated : 24th September, 2002

Kshyana Prava Samal.

(KSHYANA PRAVA SAMAL)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS

cm	:	centimeter.
UC	:	Uniformity Coefficient.
EU	:	Emission Uniformity.
fig.	:	figure.
ha	:	hectare.
ha.m	:	hectare metre.
lit	:	litre.
lph	:	litre per hour.
m.	:	metre.
min.	:	minute.
mm	:	millimeter.
ml	:	millilitre.
M.ha	:	million hectare metre.
m^3	:	cubic metre.
ppm	:	parts per million.
pH	:	Negative Logarithm of Hydrogen Ion concentration.
PVC	:	Poly Vinyl Chloride.
q/ha	:	quintal/hectare.
Rs	:	Rupees.
$	:	dollar.
&	:	and.
μ	:	micron.
%	:	percentage.
^{0}	:	degree.

LIST OF ABBREVIATIONS

ASAE	:	American Society of Agricultural Engineers.
CRIDA	:	Central Research Institute for Dry Land Agriculture.
CAET	:	College of Agricultural Engineering and Technology.
Dept	:	Department .
FAO	:	Food and Agricultural Organization .
FTA	:	Female Thread Adopter.
INCID	:	Indian National Committee on Irrigation and Drainage.
IW/CPE	:	Irrigation Water per Cumulative Pan Evaporation.
JTU	:	Jackson Turbidity Unit.
LDPE	:	Low Density Polyethylene.
LLDPE	:	Linear Low Density Polyethylene.
LSI	:	Langelier Saturation Index.
NCPA	:	National Committee on the Use of Plastics in Agriculture.
NTU	:	Nethalo Turbidity Unit.
OUAT	:	Orissa University of Agriculture and Technology.
PDC	:	Plastic Development Centre.
TNAU	:	Tamilnadu Agricultural University, Coimbatore.
WTCER	:	Water Technology Centre for Eastern Region.
WUE	:	Water Use Efficiency.

Chapter-I

INTRODUCTION

INTRODUCTION

India has around 160 million ha of cultivated land .Out of this only 35% area having assured irrigation and remaining 65% area is dependent on vagaries of monsoon. This 65% area contributes about 40% of the food production and that indicates its poor productivity level. Due to increasing cost both physical and environmental, new big irrigation systems are no more feasible and therefore, rainwater harvesting and management has become crucial for agricultural production system. It is possible to develop appropriate rainwater management strategies in conjunction with irrigation systems in these regions for increasing productivity of land, by 100 to 200% on sustainable basis using bottom up approach. Though India's water resources are good, the harnessable water is only about 115 M ham out of 400 M ham of rainfall (Unevenly distributed), 70M ham from surface and 45M ham from ground water which can irrigate about 130-140M ha. This is only about 50-60% of the gross cultivable area in the country. The rest can only be managed by the efficient utilization of harvested rainwater.

Rainwater harvesting for full filing domestic and agricultural land is as old as human civilization itself. However, it's role varies as per the climatic conditions of the region. In arid and semi arid regions the role of rainwater management is to provide life saving irrigation to kharif crop to save it from vagaries of monsoon. This reduces the instability in yield and provides cushion to subsistence level agriculture against rainfall variations. However, the situation is different in this region having high rainfall where rainwater management has a potential of being an irrigation water resource which can provide full irrigation in conjunction with rainfall to a transplanted rice based two crop rotation and a proper development of rainwater management systems has potential of substantially increasing the irrigation. As this water is limited stored at significant cost, it should be utilized as efficiently as possible at appropriate cost.

The efficient advanced and sophisticated methods generally followed are drip, sprinkler and micro irrigation system. Drip irrigation or micro irrigation is the most efficient method of irrigation. It applies water and other inputs efficiently and directly near the root zones of the plants. Irrigated areas can be doubled from the available water resources using micro irrigation. It can be installed by small as well as large farmers and is equally beneficial to both. For the operation of drip irrigation system the clogging of emitters is a major problem. The water supplied from water harvesting systems contain large no of foreign particles and contaminants. The physical quality of water plays a major role in the success of modern precision irrigation system. This is very important in case of drip irrigation as the organic or inorganic constituents present in the water clog the emitters. As gravityfed micro-irrigation/drip irrigation operates under very low pressure, the problem becomes more acute. Therefore selection of filter is very important for gravityfed drip system.

The design parameters of the drip system have been well developed, but it is mostly limited to systems which uses pump for generating pressure, and fed from ground water. For utilizing of water harvesting systems the tradition drip systems can not be used due to three reasons: (i) the size being small, pumping may not be economical and further there is gravity head available which can be used for providing necessary head, and (ii) the water is turbid requiring filters which consume less head. Cost has been a limiting factor in these applications. The cost can be reduced if some locally available and cheap material can be used as a filter fabric

Further there will be significant change in design of water harvesting system for drip irrigated crops. Thus a mathematical model is required for designing such system.

In view of above, this study has been planned with following objectives :

1. Development and design of a low cost low head efficient filter for use in gravitifed micro irrigation system
2. Study of hydraulics of gravitifed drip system for selection of suitable emitter.
3. Development of a mathematical model for design of water harvesting system for drip irrigated banana.

Chapter-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter deals with the summary of previous research works conducted in the field study and other related fields.

2.1 HISTORY AND DEVELOPMENT OF DRIP IRRIGATION

Drip irrigation was developed originally as a sub-irrigation system and this basic idea underlying drip irrigation can be traced back to experiments in Germany in 1860s. The first work on drip irrigation in the United States was a study carried out by a House in Colorado in 1913. An important break-through was made in Germany way back in 1920, when perforated pipe drip irrigation was introduced (Saroj, 2000).

During early 1940s, Symcha Blass, an Israeli engineer observed that a big tree near a leaking tap exhibited a more vigorous growth than other trees in the area, which were not reached by water from the tap. This led him to the concept of an irrigation system that would apply water in small quantity, literally drop by drop. Around 1948, green house operators in the United Kingdom began to try a similar method with some modifications. The earliest drip irrigation system consisted of plastic capillary tubes of small diameter(1 mm) attached to large pipes. Friction inside the tube restricted the flow of water into the soil from a given discharge of 2 to 10 lph. Initially, the system was installed under ground, but because of the primitive filtration techniques of the time and frequent clogging, the system moved above the ground. One of the refinements made by Blass in his original system was "Coiled emitter". Thus he developed the first patented trickle irrigation system (INCID, 1994).

Drip irrigation was introduced in India after 1970 in the agricultural universities and research institutions. Use of drip irrigation is gradually increasing through out the country. Data recorded from Department of Agriculture and Co-operation, it is found that the area under drip irrigation has gone up to 1,39,185 hectare. Among all the states, Maharashtra is the highest on area coverage by drip i.e. 27,000 hectare, followed by Karnataka with 20,700 hectare.

2.2. DRIP IRRIGATION RESEARCH IN INDIA

Research works have been taken up by various Agricultural Universities and research stations, manufacturers, farmers etc. The IPCL/NCPA has sponsored many research scheme under plasticulture development centres (PDC) to the various institutions in the country from 1985 onward. The results of various research studies under taken for the last 20 years are described briefly under each institutions.

2.2.1 TAMILNADU AGRICULTURAL UNIVERSITY, COIMBATORE, TAMILNADU

At the college of Agricultural Engineering, TNAU, Coimbatore, studies on drip irrigation are being carried out since 1970 onwards. A low cost drip irrigation system was designed and fabricated to determine the water use for various vegetables and fruit crops. Extensive experiments were conducted to study the water requirements and yields of various crops, namely tomato, radish, lady's finger, brinjal, papaya, banana, cotton and sugarcane. The results have indicated that the water requirement under drip method was about one third to one fourth of that of surface method and yield was invariably more in drip system, when compared to surface method. (G.C.,1999)

2.2.2 HARYANA AGRICULTURAL UNIVERSITY, HISAR, HARYANA

Comparative studies of drip versus surface method were conducted in small pots with onion, sugarbeet, potato and radish. It was found that drip method produced 112.0, 489.0, 344.2, 268.13 quintals per hectare of onion, sugarbeet, potato and radish respectively compared to 93.0, 418.4, 235.7 and 174.93 q/ha in surface method. Similarly water use efficiently are 2.48, 13.17, 22.95 and 29.778 q/ha/cm respectively in drip method compared to 1.84, 8.45, 11.78 and 9.43 q/ha/cm in surface method (Saroj, 2000).

In another experiment, the size of onion under surface irrigation was only 6.15 to 7.2 cm as compared to 7.71 cm when irrigated by drip method. Similarly the weight of lady's finger was only 5.67 to 6.24 kg per plant when surface irrigated as compared to 6.68 kg per plant of drip irrigated (Saroj, 2000).

2.2.3 UNIVERSITY OF UDAIPUR, JOBNER, RAJASTAN

Under the all India coordinated scheme on water management experiments on drip irrigation were conducted at Jobner. During 1974-75, trickle irrigation was tried for pomegranate and compared with check basin irrigation. It was observed that the water applied by trickle was only 76.5 lit was compared to 110.3 lit in check basin method. When the plants were given irrigation the same amount of water namely 211.50 lit in both the methods, the growth in drip irrigation was 3.22 times more than that of basin irrigation.

Similarly significant increase in production and water use efficiency of potato were observed (G.C., 1999)

At College of Technology and Agricultural Engineering of Udaipur it was reported that besides the saving in water, the yield of potato tubers was high and effect of front was minimum and weed growth was the lowest during 1970-71. During the year 1972-73 the experiment was repeated with improved design of drippers-water was given at the rate of 28.25 cm/plant/hr which resulted a saving of 47% over furrow method and yield was increased by 74.2%.

2.2.4 PUNJABRAO KRISHI VIDYAPITH AKOLA, MAHARASTRA

Experiments were conducted to compare drip with furrow method of irrigation of vegetable crops like cauliflower, tomato and brinjal. The research findings shows that 30 to 50% water is saved and substantial increase in crop yield occurs through drip irrigation. Field experiments on drip irrigation from orange crop showed that water saving was more than 50% and wetted area was 10 to 20% of the traditional irrigation system. The soil moisture content in the root zone was within 70 to 100% of the field capacity of soil in drip and accumulation of salt was found to be maximum at the periphery of wetted area. The weed infestation was minimum in drip irrigated plot. There also 20-25% saving of fertilizer was noticed (G.C., 1999).

2.2.5 UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAR, KARNATAKA

Experiments conducted at the University of Agricultural Sciences at Dharwar in Karnataka, on the evaluation of drip and furrow method of irrigation of cabbage have indicated that

(a) 46.25% of water was saved in drip method

(b) 17.65% of increased yield was obtained in drip system

(c) the weed infestation was less by 40.32% in drip system

(d) Early maturity was noticed in drip irrigation as compared to furrow irrigation.

The studies on the effect of drip irrigation compared to check basin method for grapes have revealed that the drip method resulted in 88.8% higher yield per unit of water over the control. The net return per hectare per cm of water was 39.68% more under drip system than the check basin system (Saroj, 2000).

2.2.6 JYOTHI FARM, VADODARA, GUJARAT

Experiments were conducted from 1975 onwards with drip irrigation for lime plants at Jyothi farm, Vadodara. The results have indicated that over a span of five years an average saving of 5.3% of water was observed in drip system. After 3.5 years, 50% trees under drip and 30% trees under basin irrigation started bearing fruits and the first year of fruiting was about 14% more in drip as compared to basin (G.C., 1999).

The trial conducted on groundnut has indicated that the yield was 66% higher under drip compared to border method of irrigation. This WUE under drip method was 2.8 times more than the surface method. The experiments conducted on tomato crop using drip irrigation have shown that the water saved was about 50% compared to furrow irrigation. The production of tomato per hectare per cm of water observed as 1540 kg and 1040 kg under furrow and drip method respectively due to water saving (Saroj, 2000).

2.2.7 JIVRAJBHAI PATEL AGRO FORESTRY CENTRE SURENDRABAGH, GUJARAT

Many farmers in Gujurat had introduced drip irrigation for various trees in Saurastra Region of Gujurat State. Many innovative techniques were adopted by farmers including getting water through tankers and supplying drip irrigation to reap a rich harvest much encouraging with increased yield of more that 25% and income raised by 60% (G.C. 1999).

2.2.8 CENTRE FOR WATER RESOURCES DEVELOPMENT AND MANAGEMENT, KOZHIKODE, KERALA

At the centre for Water Resources Development and Management, Kozhikode, Kerala, studies were conducted to compare the drip method with the conventional methods such as ring and basin method for coconut. Under drip method quantity of water applied was about 30 lit/day/plant. About 360 lit of water were applied once in six days (60 lit /day/plant) in case of ring and 600 lit once in six days in the basin method (100 lit/day/plant). No difference in yield was noticed among various methods. The trial conducted for banana crop has indicated that the treatments involving micro irrigation daily with mulching was superior to other treatments in saving water and crop performance. The quantity of water used for micro irrigation was 4.6 lit/plant against 20 lit in conventional method (Saroj, 2000).

2.3 MICRO / DRIP IRRIGATION

According to Buck Nakayama (1982), drip irrigation has the greatest potential where : (1) water is expensive or scarce; (2) soils are sandy, rocky, or difficult to level; & (3) high value crops are produced. In such areas, the capital expenditure on drip irrigation is offset by the reduction in cost of the expensive water & the cost of levelling. But in the alluvium belt of eastern India where water is of good quality and available in plenty at shallow depth, the advantage of drip irrigation will be in terms of the reduced size of pumping unit, decreased energy requirement and increased yields, and this may offset the capital expenditure for drip irrigation. While designing an optimal tank irrigation system, srivastava (1996) treaded off the cost of efficient application system with a reduction in the cost of storage requirement to find the optimal combination of application systems. Davis (1975) and Shoji (1977) studied the energy conservation of different irrigation methods and found that the real energy conservation under drip irrigation comes from reduced amount of pumped water because of a higher on-farm irrigation efficiency. Batty compared the installation energy (including the energy to produce plastic tubing) & annual pumping cost for nine irrigation system on a specific site. He found that flood irrigation consumes more energy than drip irrigation if the same amount of water was applied. Most of the research workers (INCID, 1994; DWMR, 1994) have reported higher yields with irrigation compared to surface irrigation.

Microirrigation is suited for undulated terrain, shallow soils and water-scarce areas. Saline / brackish water can also be used with good filtration systems. The salt stress is kept minimum at the root zone of crop with drip system as the salts are pushed to the periphery of the wetting zone by daily, drip irrigation. Hence the salt injury is avoided. The spectacular advantages of microirrigation as reported by Bucks *et al.*. (1982) are increased water-use efficiency (90-95%), higher yield (40-100%), decreased tillage requirements, high quality products, higher fertilizer use efficiency by fertigation (saving fertilizer up to 30%), lesser weed growth, less occurrence of pest and diseases, reduced labour requirement etc. Thus mcroirrigaiton chiefly offers the twin benefits of yield increase and water saving owing to that root zone of the crop is always kept nearer to field capacity. It is possible to apply water and fertilizer most precisely and uniformly to all plants by fertigation. Drip irrigation also enables re-use of poor quality waters like sewage effluents after proper filtrations.

A decade of research (1986-1988) at WTCER, indicated that the plains of eastern region are endowed with good quality ground water at shallow depths. The question is weather drip irrigation is economical in this region or not. Studies have shown that drip irrigation is economical even for shallow ground water zones (below the ground water table 3m) if the yield gain, from drip is more than 20%. The threshold value of fixed cost of drip irrigation increases sharply if electricity charges are changed from fixed tariff based on load to actual consumption even if at much lower than the actual cost of electricity. Nomographs have been developed for deciding threshold cost of drip irrigation systems. It has also been found that contrary to common perception that drip irrigation is energy intensive, the drip irrigation consumes less energy. Energy consumption is almost half if we used drip irrigation, even the size of the prime mover is drastically reduced with adoption of drip irrigation. The reduction ranges from 40 to 75%.

In the experiment of gravity fed drip irrigation system for cauliflower in mid-hills of Himalaya, the irrigation system involving collection of springs water and runoff in small low density polyethylene (LDPE) film lined tanks can be used successfully to grow vegetables even in upland areas (Srivastava, 1987 and 1988). However, due to limitation of storage capacity of tanks (10 to 100m^3), only small area can be irrigated with surface irrigation methods i.e. check basin or flood irrigation which are commonly prevalent in the valleys. Drip irrigation method provides an opportunity to minimize the unproductive losses and labour requirement and increase crop water use efficiency (Singh and Singh, 1978, Reddy *et al.*., 1990). Drip irrigation also has the potential to increase yield of most if not all, vegetable crops (Singh and Singh, 1978). Moreover due to topographical advantages of hills, gravitational energy may be utilized to operate the drips and thus, the initial and operational cost of pumping can be eliminated (Bhatnagar, *et al.*., 1998).

Many irrigated areas in the world are running increasingly short of water (Buck's, 1995), with growing competition between farmers who need to irrigate their crops and the world's rapidly expanding cities, water saving forms of irrigation are at a premium (postel, 1992). Dip irrigation, the most efficient form of irrigation currently available, now irrigates a little under two million hectares. This is less than one percent of global irrigated acreage. The main obstacle to its wider adoption is its high capital cost (Postel, 1996)- about $ 1,000 (U.S) per acre for row crops like vegetables. This makes installation of drip systems prohibitive for the great majority of farmers in developing countries who cultivate less than five acres.

In the language of economists existing drip irrigation technology is not "divisible" that is it cannot be divided into very small functional units. A typical small farmer in India cultivates five plots ranging in size from one fifth of an acre to a half acre. Biological technologies like green revolution seeds and fertilizer are divisible because they can be split into small affordable packets that fit tiny plots. But drip irrigation systems, like other current irrigation technologies, are difficult to customize to meet the needs of the small plots of poor farmers and they are too expensive to be affordable. The development of a reliable low cost drip system that fits the needs of small farmers in developing countries has long been recognized as a critical need (Hillel, 1985, Saksena, 1995; Nir, 1995). For example, Sivanappan and his colleagues tested the use of holes instead of emitters in India in the 1970s (Sivanappan and Padmakumari, 1980). To meet the need for a low cost system, International development Enterprises specializing in small scale irrigation, has developed and field tested a simplified drip system that is divisible and cost $250 a hectare ($50 for a one-half acre unit)

Pandey V.K. and Mahajan Vijay in their experiment, performance of drip irrigation in tomato in 1995-96 and 1996-97 at zonal agricultural research station, IGAU, Ambikpur, M.P to study comparative performance of drip and surface methods of irrigation in tomato (Var. Pusa early dwarf). Four intervals of water application through drip system were evaluated in terms of yield, water saving and water use efficiency. Two years pulled data showed that drip irrigation at 1 day interval produced 18% more crop yield (225.09 q/ha followed by yield 200.37 q/ha) under drip irrigation at 2 days interval and saved 20.52% irrigation water over surface method of irrigation. Water use efficiency was highest (708.55 kg/ha cm) with drip irrigation at one day interval and lowest (477.28 kg/ha.cm) with surface method of irrigation.

Experiment investment decision model for drip irrigation system showed that drip irrigation for sugarcane is economical in areas having ground water available at shallow depths, if electricity charges are at domestic consumption basis and the yield gain is more than 20%. They found that economics of drip irrigation is influenced by yield gain ratio, electricity charges, irrigation requirement and depth of ground water in that order. Davis (1975) and Shoji (1977) found that reduced amount of pumped water conserves energy in drip irrigation systems. Srivastava (1996) traced off the cost of efficient application system with a reduction in the cost of storage requirement to find the optimal combination of application system. Designing pressurized irrigation system for canal commands, Srivastava & Ahmed (1998) found that charge over to pressurized irrigation system from surface systems can save 0.855 to 2.85 ha-m of water for a 5ha command area (Srivastava and Upadhaya, 1998).

Mathematical model for designing water harvesting system for drip irrigated banana orchard was studied. It indicated that a pond-based system can irrigate a banana orchard. On canopy area basis, optimum irrigation schedule for the crop has been found at IW/CPE of 0.8. The optimal design of water harvesting system for such crop will depend upon hydrologic factors, pond site factors, plant type factors and weather parameters. The hydrologic factors will include catchment, command area ratio and runoff pattern. The pond site factors will consider size and dimensions of pond, irrigation requirement pattern, seepage loss and evaporation loss. The plant factors will be relationship between age and canopy area. These factors are interdependent and need to be analyzed together along with their constraints and contribution to objective function of minimizing the cost of irrigation. With the above view the mathematical model is being developed. The model is based on multilevel decomposition where all the factors at different levels are first considered and then merged for their interaction (James, Panda, 1999-2000).

Experiment on performance evaluation on drip irrigation system for orchard crops and shown that sapota and banana crops response to drip irrigation. Pressure compensating drippers with discharges rate of 4 lph have been installed. For sapota irrigation schedule at IW/CPE of 0.5, 0.75, 1.00 and 1.25 were evaluated under mulched and non-mulched conditions. The experiment is continuing, the experiment on banana crop was terminated in 2002. A new crop of banana was planted with optimal irrigation scheduled at IW/CPE of 0.8. To optimally utilize the drip system inter crop of brinjal was planted. This crops was irrigated by micro tubes and pressure-compensating type drippers. The hydraulics of the system was studied. Since this system was based on a pond, mathematical model is being developed for designing and optimal water harvesting system for irrigating drip irrigated banana crop (Srivastava, et.al., 1999-2000).

Bhatnagar, P.R and Srivastava R.C. (2001) had done experiment on a new drip irrigation system i.e. gravity fed irrigation system for hilly terraces. This system operates with low pressure head (mostly 0.5 –5m) and can be laid on number of terraces having varying elevations, sizes , shapes and slopes. Keeping climatic conditions of N-W Himalayas and practicability of uniform water application in view, a star layout system of micro tube emitter was designed that feed four plant rows with one lateral. This system is economical, easy to handle and have capacity to adjust the pressure head variation due to field slope, friction loss in pipes etc. Efforts were also made to develop design criteria for gravity fed drip irrigation system incorporating provisions essential to solve the problems to terrace cultivation. The criteria were demonstrated for a typical terrace system at experimental farm, VPKAS, Almora (Uttaranchal). Pilot testing on the terraces shown that the system work well with a uniformity coefficient more than 90%.

Water resource development through LDPE tanks has facilitated summer vegetable cultivation in upland areas. However, carrying over the monsoon runoff to summer involves high evaporation losses and hence adequate provision has to be kept to meet the high water requirement during summer season. Thus it is essential to reduce the water requirement of the crops through efficient application of water. Drip irrigation is one such method and due to topographical advantage, a power source is not required to operate the system by (Anonymous, 1989).With this in view, gravity fed drip irritation system has been evaluated for two crops viz. cauliflower in rabi and tomato in summer. It is evident that for cauliflower 81mm of water application through drip gave yield at par to 200mm irrigation by check basin method, resulting in a saving of about 60% water. The water saving can be further increased to 85%, if the yield is compromised by 18.8%. Similarly, for tomato there is no significant difference among different irrigation treatment and thus 46.7 mm water through drip gives yield equal to that of 120mm water through check basin, resulting in a saving of about 61.1% water. Thus, the incorporation of drip irrigation can increase the command area of an irrigation source by 2.5 times.

2.4 RAIN WATER HARVESTING

Dry land of rainfed agriculture primary dependent on rain, influences 6150 million hectares (Mha) of land world wide. It stretches over 48 countries on four continents, where 850M people derive their sustenance from it (Miller and Wali; 1994). Among the Asian countries rainfed agriculture dominates India where nearly 70% of the 1424M ha net sown area depends upon rainfall. Year after year, the fate of a large proportion of rainfed agriculture hangs in the balance because of undependable rainfall behaviour. Low yields and even crop failures often lead to fodder and food scarcity. Drought is a recurring phenomenon. During the last 120 years (1870-1990) drought struck 29 out of the 35 meterological sub-divisions of India on 425 occasions; 70 times with severe intensity (Katyal *et al.*, 1993). Lack of serious efforts to create assured water supply through scientific management of rainwater is a factor causing, recurring miseries of human being and cattle. Otherwise savings in rainfall can be handled successfully if the rain which tends to descent in a few discrete storms is managed to preserve for use during periods of drought.

Research on various aspects of soil and water conservation has been reviewed on several occasions (Tejwani *et al.*, 1975; Katyal *et al.*, 1992; Dhruvanarayana, 1993). Central Research Institute for Dryland Agriculture (CRIDA) compiled the outcome of research conducted over two decades (Anonymous., 1988) on rainwater management combined with various facets of crop production technologies relevant to diverse agro climatic regions of the country and for efficient utilisation of vast resource of rainwater for the development of sustainable rainfed agriculture.

The existing irrigation systems both government-owned and farmer managed have their limitations in terms of topography, water resource availability and cost. Thus the only alternative left to provide water to vast upland area is through utilization of very small springs and rain water harvesting. With this view, an intensive research effort was under taken at VPKAS, Almora to develop a technology package for rain water harvesting which covers the whole gamut of designing an inexpensive but seepage proof tank to store water, designing of irrigation systems based on it, development of irrigation schedules for optimal utilization of this precious water and gravity based drip irrigation for vegetables to achieve maximum water use efficiency (Srivastava *et al.* 1988a).

The rainwater (40 years average) in Orissa is 1482mm and ranges from 1378mm in Kalahandi to 1648 mm in Sundergarh with average number of rainy days varying between 65 to 78 days. However, the yields are unstable due to erratic rainfall and dry spells. In 1961-1996 there were 13 drought years, out of which five were severe (Mohapatra, 1997), but the total average rainfall of state was less than 1000mm only in three years with the lowest being 950mm in 1979. Thus the farmers of rainfed areas suffer due to erratic nature of rainfall even when the total annual rainfall is around 1000mm.

It is therefore necessary to bring these areas under irrigation to protect the resource poor farmers from the vagaries of the monsoon. This water resource can be developed by small scale runoff recycling Srivastava (1983, 1996 a), Srivastava *et al.* (1993), and Bhatnagar *et al.* (1996) have shown that small scale runoff recycling can successfully alleviate moisture stress by providing supplementary irrigation to various field crops like rice, wheat and vegetables on terraced fields of North Western Himalaya with yield comparable to fully irrigated conditions. An optimal design of runoff recycling tanks in a series by overlapping command area of one tank with catchment of succeeding tank can minimize the catchment syndrome (Srivastava, 1996 b)

The rainwater harvesting system necessary to innovate irrigation potential. However, it's role varies as per the climatic conditions of the region. In arid and semi arid regions, the role of rainwater management is to provide life saving irrigation to kharif crop to save it from vagaries of monsoon. This reduces the instability in yield and provides cushion to subsistence level agriculture against rainfall variations. However, the situation is different in this region having high rainfall where rainwater management has a potential of being an irrigation water resource, which can provide full irrigation in conjunction with rainfall to a transplanted rice based two crop rotation and a proper development of rainwater management system has potential of substantially increasing the irrigation potential (Srivastava & Panda, 1988; Srivastava, 2001)

2.5 CLOGGING OF EMITTERS .

MC Elhoe and Hilton (1974) found that improving filtration to remove particles greater than 25μ (rather than 90 μ) reduced the level of blockage over 80 days operation from 92 to 78%, but treatment with intermittent chorination at 10 ppm for 20 minuets/day on water filtered to 90 μ reduced the level blockage from 92 to 10%. Other additives with bacterial or algicidal properties had similar but less marked effects. Mcethoe and Gibson have confirmed the effect of chlorination but obtained higher levels of blockages with chlorinated sand filtered water than chlorinated screen mesh filtered water. To rectify the problem for system operation for several years without treatment Morris and Black (1973) suggested slug dosing with chlorine at 1000 ppm for 24 hr to destroy organic matter. Where bore water is used for micro irrigation the chemical composition of the water will have an important bearing on the source of clogging material and specific action to overcome each problem may be required. Peleg (1974) suggested that where precipitation of carbonates is a major source of blockages, treatment with 1% hydrochloric acid for about 10 min, will clear partially blocked system. Black (1971) suggested that this problem can be minimized if the reticulation system is buried a few centimeters below the soil surface to reduce the temperature rises, responsible for the precipitation of carbonates from the soluble bicarbonates. Biochemical precipitation of iron and sulpher produces blockages from well water in Florida (Forel *et al.* 1974). Sulphur precipitation can be reduced by reducing the pH of the water and iron precipitation may be reduced by chlorination. Calcium and oxidative iron precipitation have been successfully prevented from causing blockages in Australia (Anonymous, 1975) by injecting poly –phosphates as chelating material into the irrigation water 3-5 ppm

The study made by Bralts *et al.*, (1981) has shown that emitter plugging can be statistically included in the calculation of uniformity of emitter flow of single and dual chamber drip irrigation lateral lines. The number of emitters per plant has been shown to be important when calculating uniformity of emitter flow including emitter plugging. Remedial measures such as increased irrigation time or lateral line replacements could be made when the uniformity decreases below acceptable limits. Design curves and nomographs were also developed which simplify the inclusion of emitter plugging in design of drip irrigation lateral lines.

The successful operation of trickle irrigation system requires the reliable performances of all emitters. The major problem associated with the system is the emitter clogging which increases the operational maintenance cost and adversely affects the water distribution efficiency. Emitter clogging is directly related with the quality of irrigation water (Bucks *et al.*; 1982). Progress has been made in understanding clogging materials and various methods have been utilized to reclaim clogging (Ford, 1975; Gilbort *et al.*. 1981).

Initial attempts to overcome the clogging of drip system with filtration were partial successful (Parchomchuk ;1979). The water may also be chemically unstable, produce precipitation in the emitter. Several bacteria and algae, particularly its by product is one of the greatest contributors to the blockage which can not filter out (M.C Elhoe and Hilton, 1974 and English, 1985). It is very difficult to detect the causes of clogging and very expensive to replace clogged emitters. To determine an effective concentration and duration of application, various chemical solutions were used to reclaim the biological and chemical deposits of the clogged emitters.

Most emitters consist of narrow paths or tiny orifices. Hence, all emitters are vulnerable to resulting from physical, chemical, or biological factors (Bucks *et al.*, 1979;Gilbert and Ford. 1986). It is, therefore recommended to perform a chemical analysis on water quality before designing the system. Proper maintenance during the growing season, inspection of emitters and distribution uniformity in field to minimize the problems resulting from complete or partial plugging is necessary.(Nakayama & Bucks, 1991; FAO 1981). Most factors effective in emitter clogging exist in surface water, especially those containing sewage (Bucks *et al.*., 1979; Gilbert *et al.* 1981;Nakayama Bucks 1991). Drip irrigation system are characterized by a large number of emitters per unit area, placed on or below the ground surface, that operation of emitters is not easy to check and crop damage may occur before a plugging problem is spotted (Ravina *et al.*., 1992). To prevent emitter clogging it is recommended to start from the control head of the system. Mechanical filtration, injection of certain chemical compound for water quality treatment and flushing lateral pipe with proper frequency and timing are useful in minimizing the plugging problems (Nakayama and Bucks 1991).

Mechanical filtration is one of the main components of a trickle system. A set of filters including screen filters, centrifugal sand separators and cartridge and/or sand filters are used to entrap suspended matters (Ravina *et al.*, 1992). Most manufacturers recommended precise filtrations in design of trickle systems. When water with poor qualities used, mismanaging the system along with improper operations in filter flushing, are the most important factors resulting in emitter clogging.

Shanti R. Padmakumari O and Raman Sundar (1998) suggested that emitter clogging is the most chronic and serious problem faced by drip irrigation users. This study was conducted at Tamil Nadu Agricultural University, Coimbatare to identify the clogging agents and the exact cause of emitter clogging. Four fields were selected for the study where the drip irrigation systems were in operation continuously for a period of three years and were reported to have clogging problem. The performance of emitters for a further period of seven months was monitored to asses the effect of control measures e.g. flushing of lines and acid treatment adopted by the farmers in these fields. The study revealed that in all the four fields emitter clogging was mainly caused by carbonate precipitation due to chemical action caused by high pH and dissolved solids in irrigation water. The langelier saturation index (LSI) calculated for the water samples in these fields were +ve indicating a high potential to precipitate calcium carbonate($CaCo_3$). Flushing of lines had less effect whereas acid treatment was found to improve the flow rate of partially clogged emitters.

2.6 DRIP FILTERS

Benami (1984) used 80 mesh screen for coarser material and 150 mesh for finer material. He suggested take into account the head loss data for designing the filter. Nakayama *et al.*. (1986) reported that screen filters do an adequate job if properly sized and maintained but they are limited in their load capacity. Many of the researchers have done very good work on evaluation of filter performances. Zeier *et al.*. (1987) studied the effect of sand particle size and concentration on the performance of screen filters and reported that smaller ratio of filter pore sizes to sand particle sizes caused greater weight of sand to accumulate in the filter prior to reaching a predetermined head loss unit.

Filters are basically of two types surface filters and depth filters. In surface filters the particles larger than the opening size of a screen are removed from the filtrate whereas in depth filters particles smaller and larger than opening area trapped in their passages. Even surface filters will begin to function as depth filters when they built a cake of unfiltered material on their surface. Surface filters such as screen filters are widely used for drip irrigation. Organic matter such as algae is not easily removed from the screen filter mesh (Bruce). For this reason screen filters are used in system where low amount organic matters are present in water or are placed downline from a filtering, device that will remove these matters. Screen filters are often placed after a sand filter. However, the size of the sand filter is quite large and it increases the cost of the filter unit. Svarovsky explained the mechanism of cake formation. The filter medium has a relatively low initial pressure drop and particles of the same size or larger wedge into the opening and create smaller passages which remove even smaller particles from the fluid. A filter cake is thus formed which in turn functions as a medium for the filtration of subsequent input suspension, provided the pressure drop does not exceed the prescribed limit.

Suryawanshi S.K. & Panda R.K. (1993), in their experiment designed a drip filter unit to use different filtering materials. A filter casing was prepared out of 15 cm dia G.I. pipe. A filtering chamber to use wire mesh (80 mesh) and nylon mesh (100 mesh) as filtering material was prepared from P.V.C. pipe by drilling 5 mm holes in it, whereas for fiber materials a M.S frame was fabricated by welding 6 M.S rods of 3mm dia to two rings of 8cm dia. Tractor rubber tube was used to make gaskets. The reduction in turbidity of the flow passing through the filter was taken as the basis of evaluating the performance of the filtering materials. Turbidity is the measure of soil concentration in water. An electronic digital turbidity meter (NTM 900) was used for this purpose. A calibration curve was prepared between JTU (Jackson Turbidity Unit) value given by digital turbidity meter and known soil sustention concentrations in gm/lit.

Dash Nutan Kunar (1998) discussed drip irrigation technology for the selection of filters with reference to orchard plants. This includes a filter used in drip irrigation system, i.e. sand and gravel filter.

This filter is used for the purpose of removing organic matters from irrigation water. It is so designed that unwanted matters like algae or bacterial slime is forced down under pressure through a bed of sand gravel kept within the filter and to allow suspended solid in the water being arrested. Thereafter clean water comes out of the filter. As the sand/gravel traps sediments while in operation it is cleaned periodically by back flushing simply by reversing the filtration mechanism. This filter is strong and are designed for prolonged use in the field. They are made up of high quality of steel treated by anticorrosive chemicals and are protected by overbaked epoxy coating to ensure most effective long term non-corrosive treatment in steel products used under water and/or chemical environment. These filters are fitted with threaded / fanged / inlet / outlet.

Filter available in market are having high cost and unable to filter all types of impurities. (Howase S.S; Bhuyan R.C; and Wadatkar S.B; 2001), made an attempt to design and develop low cost filter in combination of sand filter and hydrocyclone filter for 18 cum/hr flow rate with efficient cleaning of all types of impurities. C.R. sheet was used for fabrication of sand and hydro cyclone component where as, G.I pipe fitting and hose pipe were used for flushing systems, inlet and outlet accessories and ventury attachment. The filter possed the facility of flushing the sand and hydrocyclone component separately and efficiently in addition to ventury attachment for applying liquid or water soluble fertilizer. The filter performance was tested at concentrations of 40,80,120 and 160 mg/l. It was found that the filter worked efficiently in the range of 93 to 95%. The filter was able to operate ventury for applying liquid or water soluble fertilizers effectively. The flushing systems clean sand and hydrocyclone component of the filter frequently. The cost analysis of the filter showed that the filter cost Rs 2046 only which too low as compared to that of filters available in the market. The cost of the sand cum hydrocyclone filter per hour comes to be Rs. 0.72 only.

2.6.1 Different types of Filters

The hazard of blocking or clogging necessitates the use of filters for efficient and trouble free operation of the system (Patil, 2001). The different types of filters includes:

(a) Media filters

Media filters consists of fine gravel and sand of selected sizes placed in a pressurized tank. It is required to remove organic matter such as algae mass and other vegetative material present in the water. The filters are made up of a circular tank filled with layers of coarse sand and different sizes of gravel with a provision of valves for flushing the filter assembly in case of clogging. The media filters are available in different sizes ranging from 500 to 900mm diameter with an output of 15-50 cu.m/hr respectively.

(b) Hydro-cyclone or centrifugal filters or sand separators

If the irrigation water is having more sand, hydro-cyclone type filters are required to remove the sand, it is known as vortex sand separator. Hydro-cyclone type filters are produced in various sizes for different discharges and have been found most suitable for moving particles from water before it enters the drip irrigation system. Hydro-cyclones must be followed by a screen filter as a safeguard.

(c) Screen filter

The screen filters is fitted in series with the gravel filter in order to remove the solid impurities like fine sand, dust etc. from the water. In general, the screen filter consists of a single or double perforated cylinders placed in a plastic or metallic container for removing the impurities. Generally 100 to 200 mesh screens are used in this type of filters. It must be cleaned and inspected periodically for satisfactory operation of any drip system.

(d) Spin clean filter

Incoming water is forced through a directional nozzle plate on to the inside screen. The centrifugal control of the contaminated water helps prevent debris build-up on the filters screen by constantly rotating the particles and forcing them towards the flush port by opening the flush valve, the particles may be removed.

(e) Self cleaning filter

As water passes through the filter, debris builds and up on the fine screen causing a pressure differential between the inlet and outlet of the filter. When variance goes beyond the set valve pressure, differential controller initiates a cleaning cycle. Cleaning of the screen is implemented by the suction scanner which scans and sucks up the dirt from the screen. The dirt is removed through flush valve.

(f) Lateral filters

Small poly filters have been developed and used on individual lateral lines to reduce the load on main filter. These poly filters are adaptable to various sizes and have auto flushing arrangement through which dirt from lateral gets flushed during start up and shut off of the system, which in turn reduces the maintenance cost of the system

(g) Disc filter

The filtration is obtained through compressed grooved plastic discs. The solids retained on the filter accumulate at the intersections between the grooved faces of each pair of adjacent discs. During backwash, discs are separated the jet spray causes rapid spinning of the discs while cleaning them. The dirt particles are washed out through flush port.

(h) Settling Basin

If raw water containing high suspended matter (inorganic turbidity) more than 200 ppm, a settling basin is recommended to prevent rapid clogging of the filter and to avoid excessive (frequent) back flushing

2.7 DESIGN OF DRIP IRRIGATION SYSTEM

2.7.1 Hydraulic Design Procedures

Hydraulic design procedure for drip irrigation systems are fairly well established. An important goal in their design is the determination of the head loss in the system. Lateral length and diameter, emitter spacing and flow rare, and elevation changes are important parameters which are considered in the design process. The flow regime throughout a drip irrigation system is hydraulically steady but spatially varied. Drip irrigation distribution lines are generally considered to be smooth pipes and either Darcy-Weisbach (D-W) or Hazen_Williams (H-W) equation is used to compare head losses. The latter is widely used in hydraulic design because of its simplicity (Keller and Karmali, 1975; Jeppson, 1982)., Although, according to Morris and Wiggert (1972) this formula is not recommended for calculating head loss in small diameter pipes, and at low value of Reynolds number, because it is dimensionally non-homogeneous, no account is taken on fluid viscosity, and it is high degree of turbulence. The empirically developed Hazen-Williams equation is,

$$J = 1.131 \times 10^{12} D^{-4.871}[Q/C]^{1.852} \text{ -------------------------(2.1)}$$

$$= 7.02 \times 10^{5} C^{-1.852} V^{2.436} Q^{-0.584}$$

where,

$J = H_f/L$ = Hydraulic gradient in parts per million (% = m/100m);

H_f = Head loss due to friction (m);

L = pipe length (m);

D = Inside pipe diameter (mm);

Q = Pipe flow rate (m^3/hr);

V = Velocity of flow (m/sec); and

C = Dimensionless pipe roughness factor.

Care should be taken in selecting the C- values. Hughes and Jeppson (1978) showed that the selection of the proper C value for equation (2.1) obviously depends on the Reynolds number R_e: and Howell *et al.*, (1980) suggested that the best C values for drip irrigation systems were C = 130 for 14-15mm pipe, C = 140 for 18-19 mm pipe and C = 150 for 25-27mm pipe. A low estimate of C will over estimate that friction loss, where as a high estimate will result in more conservation friction loss for design purposes.

Pressure variations along a drip irrigation line are primarily due to friction and slope. The flow of water in a pipe with a number of equally spaced outlets has less total friction than if the flow remained constant in a similar pipe line with the same inside diameter and length, but no outlets. Christiansen (1942) developed the concept of the 'F' factor that accounts for this effect. Therefore the friction head loss in a pipe with multiple outlets, H_f is given by,

$H_f = H_f \times f$ --------(2.2)

Where,

'f' is the friction factor (fraction); and

H_f = Absolute head loss from pipe friction.

2.7.2 Research on design of drip irrigation

Wu and Gitlin (1974) developed a design chart, which can be used to design a drip irrigation line by considering an acceptable value of uniformity and trying with different combination of pressure (H) and length (L) to find a suitability for field conditions.

Wu (1975) concluded that a straight energy line can be used to design main lines for drip irrigation system. He developed a very simple technique for selecting main line size, which can be adopted for all topographic and slope condition.

Wu and Gitlin (1977) developed design charts for sub-main. In general the sub-main length in short and size in designed for single size. Discharge is the most important factor here.

Karmoli (1977) reported that the cross section of the flow path would be quite narrow for producing along drip in pressure and obtaining low discharge. The requirement of low discharge with high pressure drip and large flow cross section and contradictory and this has led to the development of drippers with pressure compensation capabilities.

Gillespie *et al.*, (1979) developed some mathematical expression for lateral lines relating to pressure heads, and or different types of uniform slope conditions but without changing the length of the emitter lines.

Khatri *et al.*. (1979) conducted laboratory experiments and showed that Darcy-Weisbach equation for hydraulically smooth pipe can be used to represent friction drop relations for micro tubes with a size ranging from 0-8 mm to 4mm, they had also derived some empirical relationship and designed charts with the help of some empirical equations.

Ammoozegar-ford *et al.*. (1984) developed nomographs to be used in the design and operation of drip irrigation system. The plant rating geometry, uptake rate, soil properties and the drip irrigation design parameters are related in the nomographs to the soil moisture status.

Wu (1985) developed uniplot technique for drip irrigation lateral and sub-main design. He used the line slope and allowable pressure variation to form a better reference area. This method can be used for both uniform and non-uniform slope conditions and also for single or multi size lateral or sub-main design.

Yitayew and Warrik(1987) studied the effect of velocity and total energy drop. They observed that the total energy drop was greater in turbulent flow compared to laminar flow irrespective of velocity head. The relative error in total head by neglecting velocity head was higher for laminar flow than turbulent flow. Hence, they suggested not to neglect the change in velocity head for long laterals and laminar flow regimes.

2.7.3 Emission uniformity (EU)

The term emission uniformity has generally been used to describe the emitter flow variation for a trickle irrigation unit or sub-unit. Emission uniformity can be a function of : (i) hydraulic variation caused by elevation changes and friction losses along distribution lines and (ii) emitter discharge variation at a given operating pressure caused by manufacturing variability, clogging, water temperature changes, and aging. Presently, no design equation has been developed that includes all the factors which might affect emission uniformity.

With sprinkler irrigation system, the co-efficient of uniformity (Christiansen 1942), has been widely accepted and can be expressed as,

$$C_u = [\ 1-(\Delta q/\ \bar{q})]\ 100 \text{ ----------(2.3)}$$

Where, $\bar{q}$ is the mean sprinkler discharge rate and Δq is the mean absolute variation of sprinkler discharge rates. All among that the sprinkler discharge rates are normally distributed.

Hart (1961) developed the following:

$$C_u = (1-0.798C_v)100 \text{ -----------(2.4)}$$

Where, C_v is the co-efficient of variation (statistically, the standard deviation divided by the mean) between the discharge rates.

Keller and Karmal: (1975) were first to define an empirical design emission uniformity percentage EU for drip irrigation system as,

$$EU = [\ 1-1.27\ (C_{vm})\ n^{-1/2}]\ (q_n/\ \bar{q})\ 100 \text{ ------------(2.5)}$$

Where, C_{vm} is the manufacturers co-efficient of variation. 'n' is the number of emitters per plant (minimum one).q_n is the minimum emitter discharge rates. The EU increases as more emitters are added to each plant.

Nakayama *et al.* (1979) developed a co-efficient of design uniformity C_{ud} based on statistical analysis:

$$C_{ud} = [1-0.798\ (C_{vm})n^{-1/2}]100 \text{ ------(2.6)}$$

Equations (2.5) & (2.6) stress the importance of manufacturing variability and the number of emitters per plant. However, the original derivation of EU was based on the ratio of the discharge rate for the low cost 25% of emitters to the average discharge rate, where as C_{ud} is based on the discharge rate variations from the average rate.

Wu and Gitlin (1977) proposed another parameters called emitter flow variation, defined as,

$$q_{var} = [\ 1-(q_n/q_m)]100 \text{ -------------- (2.7)}$$

where, q_n and q_m are the minimum and maximum emitter rates

Bralts *et al.* (1981) illustrated for single-chamber trickle irrigation tubing that the hydraulic and manufacturing variability where independent and that the total co-efficient of variation C_{vt} can be expressed as,

$$C_{vt} = (C^2_{vh} + C^2_{vm})^{1/2} \text{ ---------(2.8)}$$

Where, C_{vh} is the hydraulic co-efficient of variation

The most widely used formula of EU (Karunakaran, 1990):

$$EU = \frac{\text{Minimum rate of discharge per plant}}{\text{Average rate of discharge per plant}} \times 100 \text{ --------(2.9)}$$

General criteria for EU values for systems which have been in operation for one or more season are:

(i) EU > 90%- Excellent

(ii) EU = 80 to 90%- Good

(iii) EU = 70-80% - Fair

(iv) EU < 70%- Poor

2.7.4 Distribution network of drip system

The distribution network mainly constitutes main line, sub-main line and laterals with dripper and other accessories (Michael, 1997).

(i) Main line, Sub-main line

Generally rigid PVC and high density polyethylene (HDPE) pipes are used as main line. Pipes of 63 mm diameter and above, with a pressure rating of 4 to 6kg/sq cm are recommended for main pipes. These pipes laid underground, offer a long life of more than 20 years.

For sub-main pipes, rigid PVC, HDPE or LDPE are recommended. Pipes having an outer diameter ranging from 32mm to 75mm with a pressure rating of

2.5 kg/sq.cm are used as sub-mains. These pipes may be laid above the ground or underground.

(ii) Laterals

The laterals are normally manufactured from LDPE. These pipes are generally laid above the ground. Recently a better material than the presently used LDPE i.e. Linear low density polyethylene (LLDPE) is being used. The LLDPE gives more protection against ultra violet rays and longer life of pipe than LDPE. Generally pipes having 10,12,16 and 20mm internal diameter with wall thickness varying from 1 to 3mm are used in drip system.

(iii) Drippers/Emitters

Drippers function as energy dissipaters, reducing the inlet pressure head (0.5 to 1.5 atm) to zero atmosphere at the outlet. These drippers are generally manufactured from poly propelene material. These drippers can be classified as inline and online drippers.

Chapter-III

MATERIALS AND METHODS

MATERIALS & METHODS

This chapter deals with different materials, methodologies utilized for the design of low cost filters.

3.1 FABRICATION OF FILTERS

Low cost filters were fabricated to reduce the cost of filters. The body of the filter was made by cutting a PVC pipe of 140mm dia meter, to a length of 45 cm. Two end caps were fixed at two ends. The buttom end was permanently fixed and the upper end was kept removable, so that it can be removed if required to clean the filter. A 50mm dia PVC pipe (blue) was used as the base pipe for the filter. It was threaded at both ends and the upper end was covered by an end cap. The lower end was inserted through the fixed end of the outer tube. The joint was thoroughly packed to prevent leakage of water. The body of the inside pipe was drilled through, so that water can be filtered through it. The bottom threaded portion of the pipe was joined to the submain through a FTA (Female thread adopter).

The same set-up was used for five different filters using different combination of filter materials.

1. Coconut coir filter
2. Jute filter
3. Mesh filter
4. Mesh with coir filter
5. Mesh with jute filter

PLATE NO. 1. Fabrication of low cost filter.

PLATE NO. 2. Low cost filter.

3.1.1. Coconut coir filter:-

Coconut coir was loosened and washed with clean water till all the small particles were removed. It was inserted in the annular space between the outer pipe and inner pipe of the filter. The inner pipe was not covered with any net. The coir was filled in a compacted way so as to improve filtration efficiency. The diagram of this filter is shown in figure - 3.1.

3.1.2. Jute Filter:-

Jute filters were loosened and washed with clean water till all the small particles were removed. Then it was cut into pieces of approximately 15cm length and kept in the annular space of the filter. No net was put around the inside pipe. The jute was similarly compacted to increase the filtration efficiency. The diagram of this filter is shown in figure-3.2.

3.1.3. Mesh Filter:-

A nylon net having net sizes 1mm was taken according to the size of the filter. A layer of net was rapped around the 50mm inner PVC pipe and for proper fixation, it was tied with G.I. wire. The diagram of this filter is shown in figure-3.3.

3.1.4. Mesh with coir filter:-

The nylon mesh of 1mm net size was rapped around the inner pipe of the filter with G.I. wires. Along with that, the loosened coconut coir was placed in the annular space of the filter. The diagram of this filter is shown in figure-3.4.

COIR FILTER

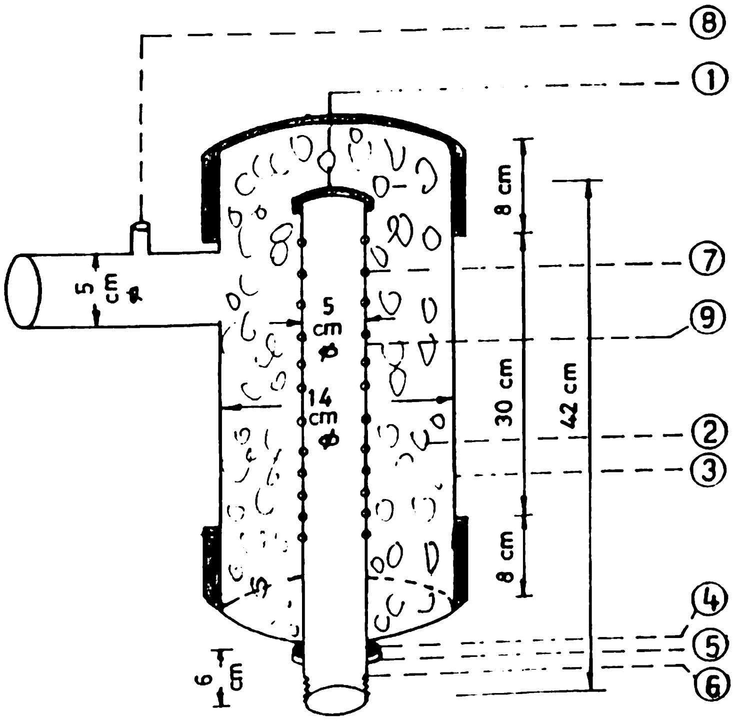


FIG. 3.1

① TOP CAP
② COCONUT COIR
③ PVC PIPE (14 cm DIA)
④ WASHER
⑤ CHECK NUT
⑥ THREADED PORTION
⑦ PORE SPACES
⑧ INLET PR. GAUGE
⑨ PVC PIPE (5 cm DIA)

JUTE FILTER

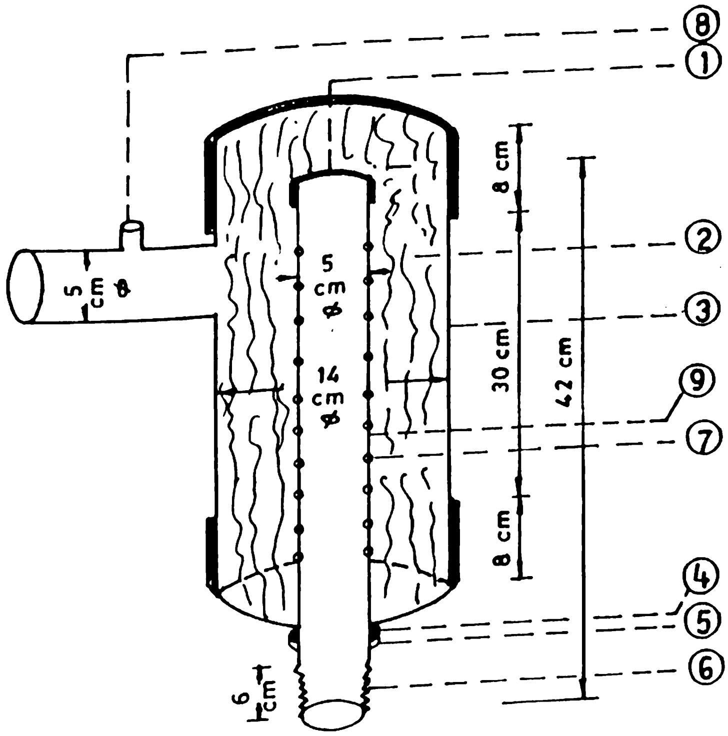
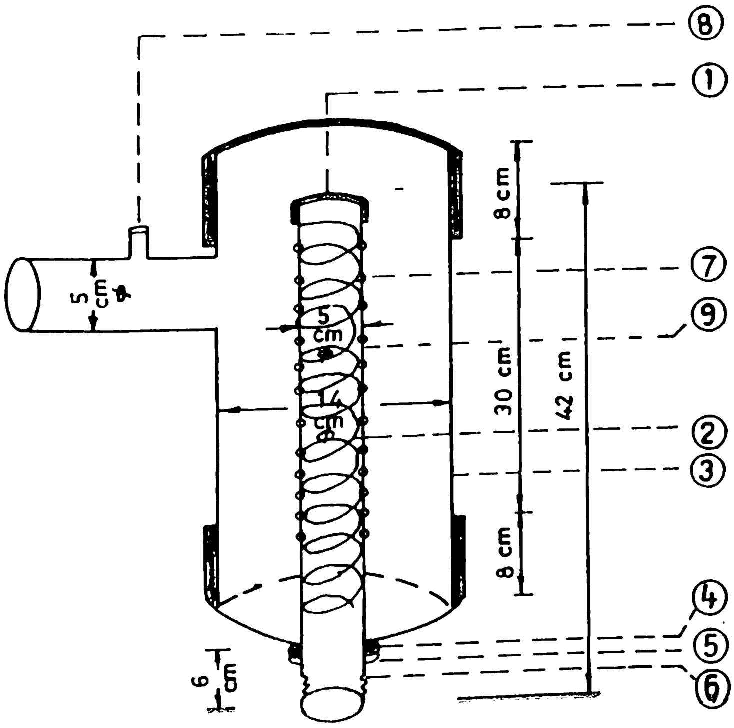


FIG. 3.2

① TOP CAP
② JUTE
③ PVC PIPE
④ WASHER
⑤ CHECK NUT
⑥ THREADED PORTION
⑦ PORE SPACES
⑧ INLET PR. GAUGE
⑨ PVC PIPE (5 cm DIA)

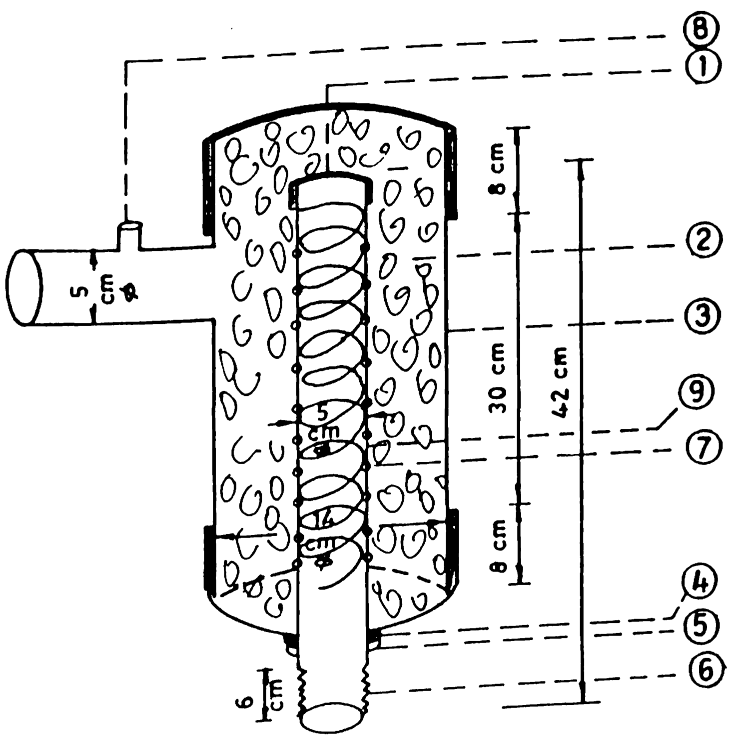
MESH FILTER



① TOP CAP
② MESH
③ PVC PIPE (14 cm DIA)
④ WASHER
⑤ CHECK NUT
⑥ THREADED PORTION
⑦ PORE SPACES
⑧ INLET PR. GAUGE
⑨ PVC PIPE (5 cm DIA)

FIG.3.3

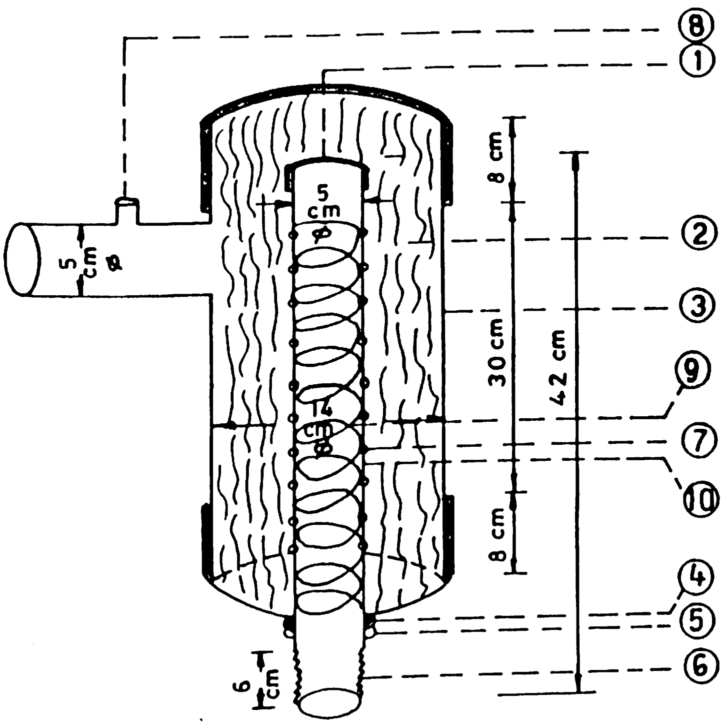
MESH + COIR FILTER



① TOP CAP
② COIR
③ PVC PIPE (14 cm DIA)
④ WASHER
⑤ CHECK NUT
⑥ THREADED PORTION
⑦ PORE SPACES
⑧ INLET PR. GAUGE
⑨ PVC PIPE (5 cm DIA)

FIG.3.4

MESH + JUTE FILTER



1. TOP CAP
2. JUTE
3. PVC PIPE (14 cm DIA)
4. WASHER
5. CHECK NUT
6. THREADED PORTION
7. PORE SPACES
8. INLET PR. GAUGE
9. MESH
10. PVC PIPE (5 cm DIA)

FIG.3.5

SCREEN FILTER

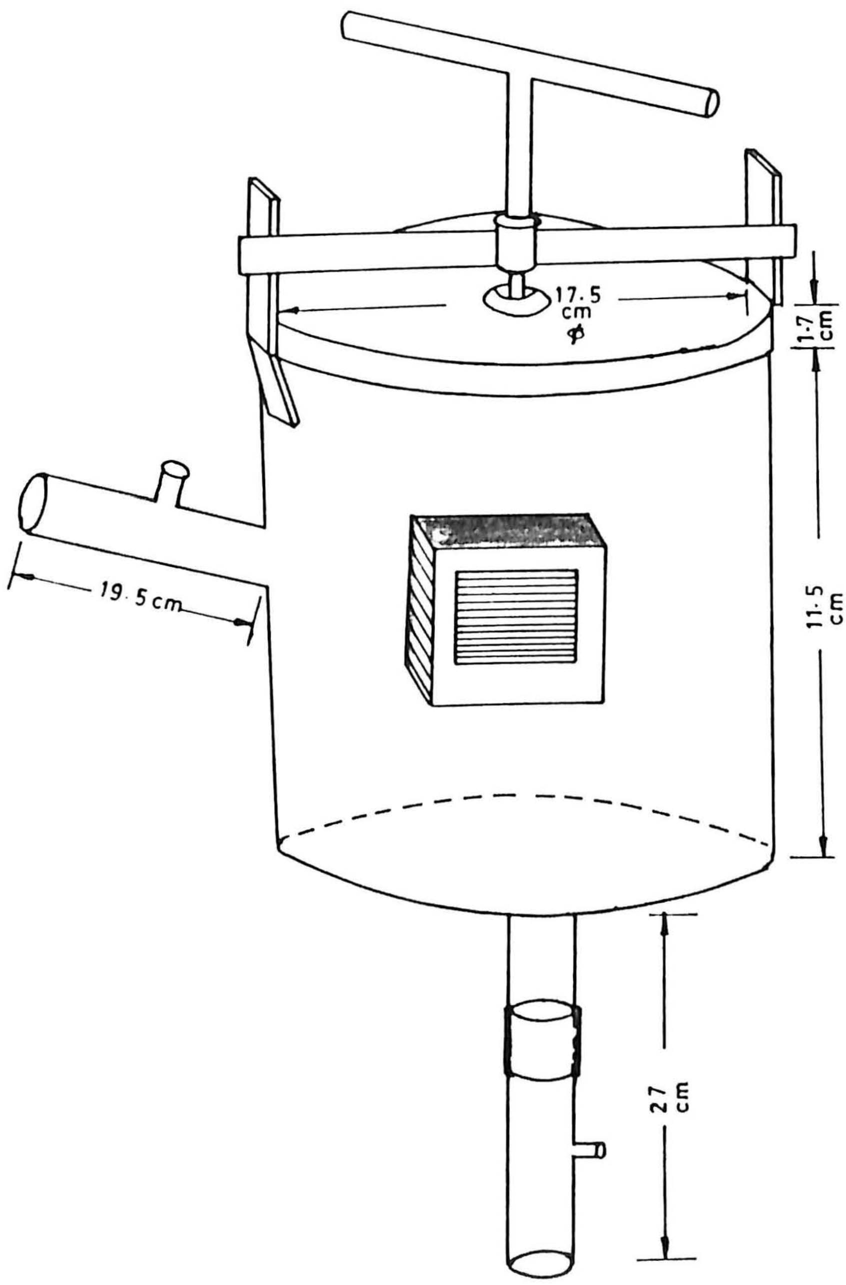


FIG. 3.6

3.1.5. Mesh with jute filter:-

The nylon mesh of 1mm net size was rapped around the inner pipe of the filter with G.I wires. Along with that the loosened jute was placed in the annular space of the filter. The diagram of this filter is shown in figure-3.5.

These five low cost fabricated filters were compared with a conventional screen filter (EPC irrigation manufacture).

3.1.6. Screen filter:-

Screen filter is used for removal of inorganic foreign matters from water such as sands and small stones which adversely affect the performance of the system. When the used water is turbid, the screen filter is used in series with sand filter. Screen filter consists of a single perforated cylinder placed in a metallic container for removing the impurities. Generally 100 to 200 mesh screens are used in this type of filters. The diagram of this screen filter is shown in figure–3.6.

3.2 MEASUREMENT OF TURBIDITY

3.2.1 Turbidity: Turbidity in water is caused by suspended matter such as clay, silt, finely divided organic and inorganic matter, solubles, coloured organic compounds and plankton and other microscopic organisms. Turbidity is an expression of optical property that ceases light scattering properties of suspension in the sample. Optically black particles such as those of activated carbon may absorb light and effectively increase turbidity measurements.

The Digital Turbidity meter was used for measurement of turbidity upto 1000 NTU

3.2.2 Operating instructions

All the parts like display, test tube holder, range switch, set zero, calibrate on/off switch and test tube holder cover were checked before using the instrument.

3.2.3 Installation

During installation of the instrument the following points must be taken into consideration.

1. The power supply was of 230V, 50 Hz AC supply. Proper grounding of the instrument was ensured for its smooth operation and safety of the operator.
2. A 3 pin plug in 5amp was connected to AC voltage supply socket.
3. The environment was free from dust.
4. The instrument was placed on a strong vibration free working bench.
5. Room temperature was between 5^0 to 45^0 C.
6. Humidity was not more than 90%.
7. Then switch was kept on.
8. A test tube containing distilled water was kept in the test tube holder.
9. The '000' zero was set by rotating the SET ZERO knob.
10. Then the instrument was set ready for use.

3.2.4 Calibration :

3.2.4.1 Reagent Preparation

Turbidity free water: The distilled water was taken for testing as turbidity free water.

Stock Turbidity Suspension

Soln-I: 1.000 gm of hydrazine sulphate $[(NH_2)_2\ H_2So_4]$ was mixed with distilled water in a 100ml volumetric flask and the Solution was made upto mark, to make it 100ml.

Soln-II:10.00 gm of hexamethylenetetramine $(CH_2)_6N_4$ was mixed with distilled water and diluted to 100ml in the 100ml volumetric flask.

Then 5ml of Solution I and 5ml Solution-II were allowed to stand for 24 hours at 25 ± 3^0C and then it was made to 100ml in a volumetric flask. The turbidity of the suspension was tested and found 400 NTU.

Standard Turbidity Suspension

Another standard turbidity suspension was also made for getting a range of 100 NTU by mixing 25ml of suspension (Prepared) and 75ml of water.

3.2.4.2 Calibration

→ The switch of the instrument was kept on for sometime to be warmed up.

→ The appropriate range was selected depending upon the expected turbidity of the sample.

PLATE NO. 3. Preparation of standard turbidity suspension for calibration.

→ The '0' of the instrument was set with turbidity free water using a blank Solution by 'set zero' knob.

→ Then standardization was done for both the cases, 100 NTU and 400 NTU solution by using calibration knob.

→ Now the instrument was found to take the reading.

→ Then the unknown solution was kept and reading was taken.

3.2.5 Precautions :

→ Sample test tube should be cleaned inside and outside, in case any scratched or etched should be discarded.

→ The test tube should not be touched at the sides only the top end should be hold.

→ The test tube with samples should be thoroughly agitated and sufficient time should be allowed to make the solution air bubble free before taking the reading otherwise it will give misreading.

→ At the time of taking reading the test tube should coincide with the mark on the instrument panel.

3.2 EVALUATION OF DRIP IRRIGATION SYSTEM

For evaluation of drip irrigation system, different types of emitters were selected and evaluated for their performance.

In the present work, four different drip emitters are tested. They are

1. Online drippers
2. Inline drippers
3. Micro tubes
4. Micro sprinkler

3.3.1 Online drippers:

Drippers function as energy dissipaters, reducing the inlet pressure head (0.5 to 1.5 atm.) to zero atmosphere at the outlet. These drippers are generally manufactured from poly propelene material. These drippers can be classified as online and inline drippers. The online drippers are fixed on the lateral by punching suitable size holes in the pipe. These drippers can be classified into pressure compensating and non pressure compensating type.

3.3.2 Inline drippers:

Inline drippers are fixed along the line. The inline drippers have generally a simple thread type and labyrinth type flow path. With the labyrinths type flow path, it is possible to have larger cross section area and turbulent flow of water to prevent clogging of drippers. The inline drippers are available with discharge of 2,3,4,8 lph at 1 atmosphere pressure. These drippers can be fixed in 10 to 13mm internal dia pipes.

3.3. 3 Micro tubes :

Micro tubes are simple 1.2mm LLDPE pipes which are inserted into laterals. Due to its small diameter, controlled amount of water is discharged. Discharge of the micro tubes can be varied by changing the length of the micro tube.

PLATE NO. 4. System with online drippers.

PLATE NO. 5. System with inline Drippers.

PLATE NO. 6. System with microtubes.

3.3.4 Micro sprinkler :

Micro sprinkler is a low volume sprinker that can be operated at low pressure. It requires less energy than the conventional sprinkler system and is less susceptible to clogging drip emitters.

3.4 EXPERIMENTAL SET UP

A PVC pipe of 165mm dia was put vertically and the bottom was closed. The top portion was kept open to put the water of desired turbidity. A bypass pipe was arranged at the top of the 165mm pipe to provide uniform head to the system. A 50mm dia PVC pipe was fixed towards the bottom of the main pipe, so that the water can be available to the filter through this pipe. The other end of the 50mm PVC pipe was joined with the inlet of the filter through a G.I union. The outlet of the screen filter was attached to a sub-main pipe of 50mm dia through a FTA. A lateral was attached to the sub-main pipe through a gromate take off. The drippers and micro tubes were attached to separate 16mm laterals at a 60 cm spacing each. To measure the head loss through the filter, two numbers of transparent flexible plastic pipes were fixed to the inlet and outlet of the filter by brass nipples. The head loss was measured by using manometer

EXPERIMENTAL SET-UP OF LOW COST FILTER

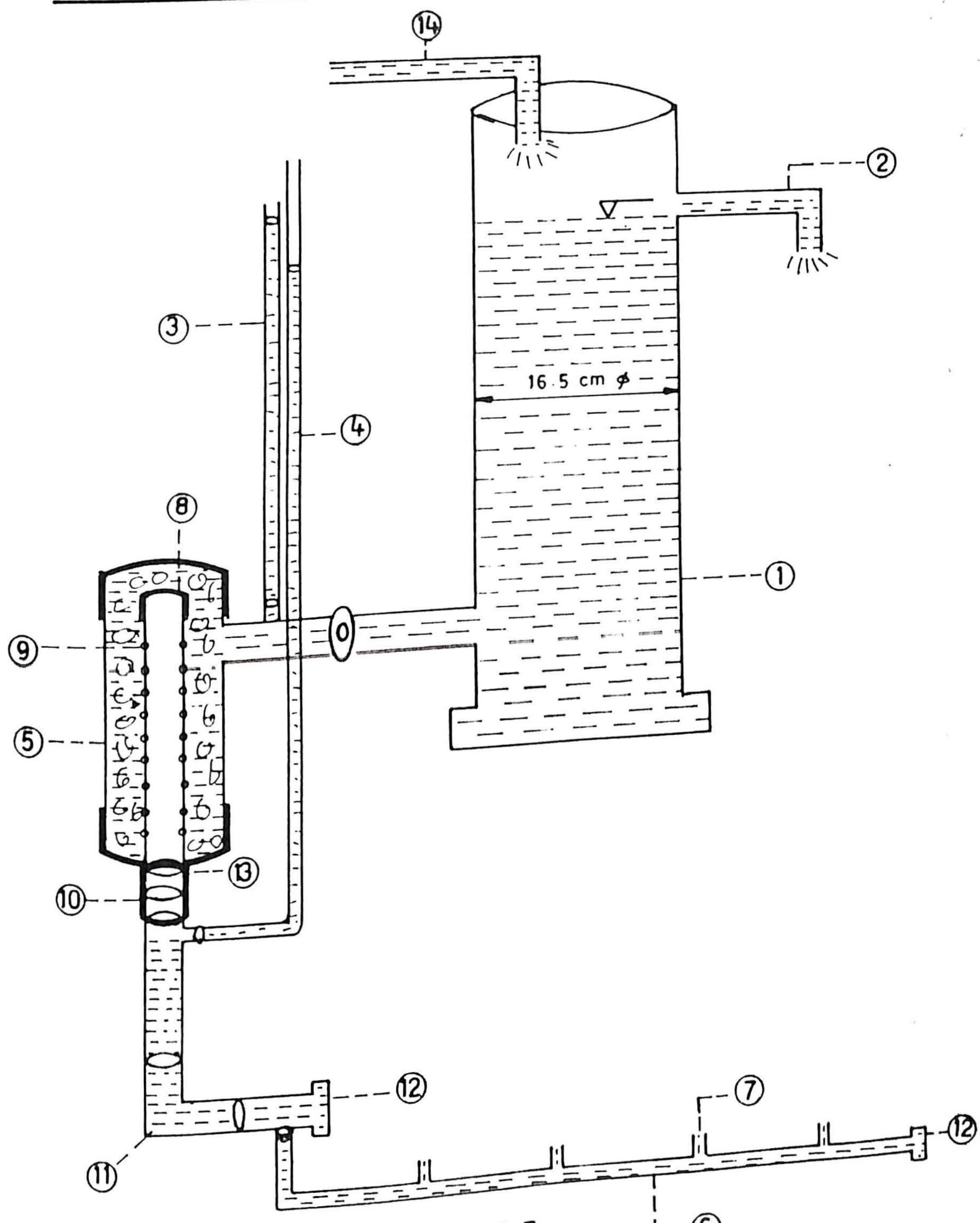


FIG.3.7

1. PVC PIPE
2. OVER HEAD PIPE
3. INLET PRESSURE GAUGE
4. OUTLET PRESSURE GAUGE
5. LOW COST FILTER
6. LATERAL
7. EMITTER
8. TOP CAP
9. PORE SPACES
10. FEMALE THREAD ADOPTER
11. PVC ELBOW
12. END CAP
13. WASHER + CHECK NUT
14. INCOMING WATER

PLATE NO. 7. Screen filter before set up.

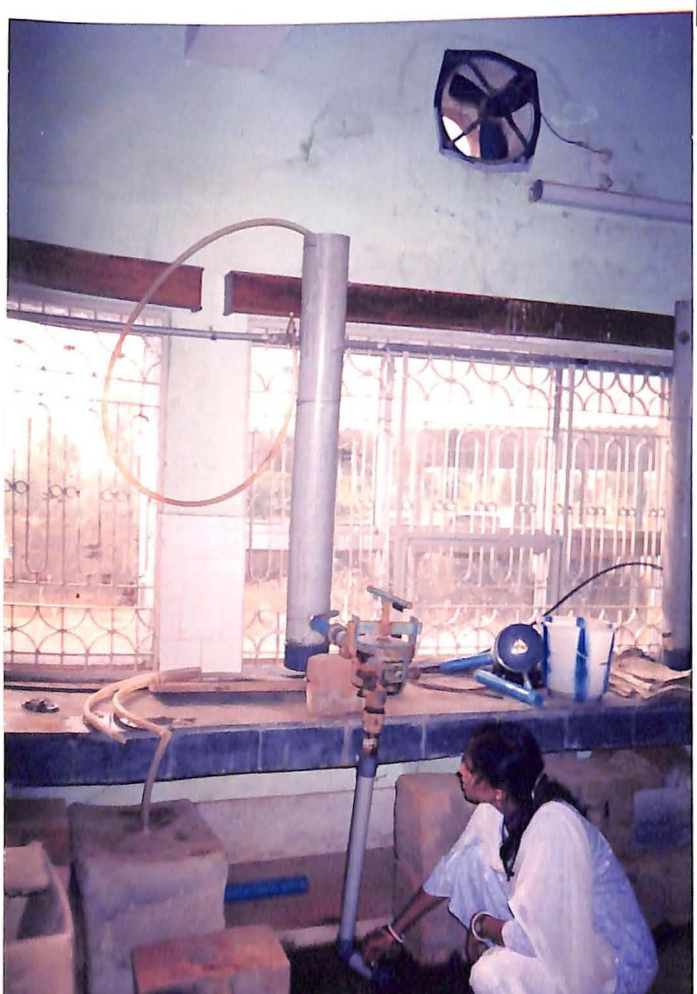


PLATE NO. 8 . Experimental set-up for screen filter.

PLATE NO. 9. Experimental set-up for low cost filter.

PLATE NO. 10. Measurement of discharge using microtubes.

PLATE NO. 11. Measurement of discharge using drippers

PLATE NO. 12. Measurement of head loss using mercury mano meters.

PLATE NO. 13. Measurement of head loss using water manometers.

3.5.3 Measurement of filtration efficiency:-

The filtered sample water was collected for cleanwater,30ppm, 50ppm solution before and after filtration separately. The turbidity values were measured in NTU units by using digital turbidity meter. The head loss across the filter was determined by measuring the difference of pressure gauges readings provided at the inlet and out let end of the filter.

The filtration efficiency was determined by the equation

$Fe=100(1-s_0 \, si)$

Where, fe= filtration efficiency,(%)

So = component concentration at the filter outlet.

Si = component concentration of initial feed in the filter

Filtration efficiency were computed for all filters and are shown in Table 4.3.

3.5.4 . Measurement of uniformity coefficients

For measurement of uniformity coefficient steel cans for each drippers / microtubes were placed in a line to collect samples. The system was operated continuously for a certain period. Then all the cans were removed at a time. The water collected in each can was measured with the help of measuring cylinders. Uniformity coefficient was determined by using the following equation by Christiansen (1942)

$$Cu = 100\left(1.0 - \frac{\sum x}{mn}\right)$$

Where, Cu = Uniformity coefficient, percent

X = Numerical deviation of individual observed amount, from average amount.

m = average amount of all observations.

n = total number of observation points.

The computed value of Uniformity coefficient are placed in Table 4.4.

3.5.3 Measurement of filtration efficiency:-

The filtered sample water was collected for cleanwater,30ppm, 50ppm solution before and after filtration separately. The turbidity values were measured in NTU units by using digital turbidity meter. The head loss across the filter was determined by measuring the difference of pressure gauges readings provided at the inlet and out let end of the filter.

The filtration efficiency was determined by the equation

$$Fe = 100(1 - s_0 \, si)$$

Where, fe = filtration efficiency,(%)

So = component concentration at the filter outlet.

Si = component concentration of initial feed in the filter

Filtration efficiency were computed for all filters and are shown in Table 4.3.

3.5.4 . Measurement of uniformity coefficients

For measurement of uniformity coefficient steel cans for each drippers / microtubes were placed in a line to collect samples. The system was operated continuously for a certain period. Then all the cans were removed at a time. The water collected in each can was measured with the help of measuring cylinders. Uniformity coefficient was determined by using the following equation by Christiansen (1942)

$$Cu = 100\left(1.0 - \frac{\sum x}{mn}\right)$$

Where, Cu = Uniformity coefficient, percent

X = Numerical deviation of individual observed amount, from average amount.

m = average amount of all observations.

n = total number of observation points.

The computed value of Uniformity coefficient are placed in Table 4.4.

3.5.3 Measurement of filtration efficiency:-

The filtered sample water was collected for cleanwater,30ppm, 50ppm solution before and after filtration separately. The turbidity values were measured in NTU units by using digital turbidity meter. The head loss across the filter was determined by measuring the difference of pressure gauges readings provided at the inlet and out let end of the filter.

The filtration efficiency was determined by the equation

$Fe=100(1-s_0 \, si)$

Where, fe= filtration efficiency,(%)

So = component concentration at the filter outlet.

Si = component concentration of initial feed in the filter

Filtration efficiency were computed for all filters and are shown in Table 4.3.

3.5.4 . Measurement of uniformity coefficients

For measurement of uniformity coefficient steel cans for each drippers / microtubes were placed in a line to collect samples. The system was operated continuously for a certain period. Then all the cans were removed at a time. The water collected in each can was measured with the help of measuring cylinders. Uniformity coefficient was determined by using the following equation by Christiansen (1942)

$$Cu = 100\left(1.0 - \frac{\sum x}{mn}\right)$$

Where, Cu = Uniformity coefficient, percent

X = Numerical deviation of individual observed amount, from average amount.

m = average amount of all observations.

n = total number of observation points.

The computed value of Uniformity coefficient are placed in Table 4.4.

PLATE NO. 14. Measurement of filtration efficiency using Digital turbidity meter.

3.6 MATHEMATICAL MODEL FOR DESIGNING WATER HARVESTING SYSTEM FOR DRIP IRRIGATED BANANA ORCHARD.

Banana is a crop which gives fruiting within one year and its main trunk is cut after harvest of fruit and sucker is allowed to grow. In tropical climate, it can be planted any time. WTCER (2000) has found that irrigation schedule at IW/CPE = 0.8 based on canopy area gives the best result. Thus the water requirement of the crop will vary as per the growth stage, with low water requirement during initial stage and higher at later stage. However the water availability in tank will be maximum during autumn and least during summer. Further the cost of carrying over a particular amount of water in summer will be higher as there will be additional storage requirement to cover seepage and evaporation losses. These factors are interrelated and a mathematic modelling is required for designing the system. The design parameters will be (i) timing of planting, (ii) tank size (iii) required catchment command area ratio, (iv) hydrological characteristics of the catchment and (v) threshhold value of seepage too.

The objective function will be to minimize the cost of the tank, i.e.

Min

$Z = CVT$

$$\therefore VT = \left[\sum_{i=n}^{i=n+45} R \cdot CA_i (E_i - P_i) .3000 + \sum_{i=n}^{n+45} LE_i + LS_i \right] \frac{1}{1000} + 500$$

Where,

$CA_i = f(i)$

Estimation of evaporation loss :

$$LE_i = 0.7\, E_i \left\{ W - 2F - 2\sum_{i=1}^{i-1} (d_i + s_i + e_i) \right\} \left\{ L - 2F - 2\sum_{i=1}^{i-1} (d_i + s_i + e_i) \right\}$$

Where,

$$d_i = \left[WL - 2\left(F + \sum_{i-1}^{i-1} d_i + S_i\right)(W + L) + \left(F + \sum_{i-1}^{i-1} d_i + S_i\right)^2 + 4\left(h - \sum_{i=1}^{i-1} d_i + S_i\right)^2 \right.$$

$$- \{[- WL + 2\left(F + \sum_{i=1}^{i-1} d_i + S_i\right)(W + L) + \left(F + \sum_{i=1}^{i-1} d_i + S_i\right)^2 + 4\left(h - \sum_{i=1}^{i-1} d_i + S_i\right)^2\Big]^2$$

$$- 4 \cdot V_i\left(W + L - 2F - 2\sum_{i=1}^{i-1} d_i + S_i - 4h\right)\Big\}^{1/2} \Big/ 2\left(W + L - 2F - 2\sum_{i=1}^{i-1} d_i + S_i - 4h\right).$$

$$V_i = R \cdot CA_i \cdot (E_i - P_i)/n$$

d_i = depth of water lost due to irrigation in the i^{th} week

CA_i = Canopy area (m^2) in i^{th} week

E_i = open pan evaporation during in i^{th} week, mm.

P_i = Precipitation during i^{th} week, mm.

LE_i = Loss of tank water due to evaporation during i^{th} week, litres

LS_i = Loss of tank water due to seepage during i^{th} week, litres.

R = Irrigation Ratio

n = number of week when crop is planted

(3000 is the number of plants per hectare)

Estimation of seepage loss :-

$$S_i = C + m\, hh_{i-1}$$

$$hh_i = h - \sum_{i=1}^{i-1} S_i + d_i$$

Where,

S_i = rate of seepage loss during i^{th} week

hh_i = depth of water during i^{th} week

h = maximum depth of water

$$LS_i = V_i - V_{i-1}$$

V_i = Volume of water in tank in i^{th} week

LS_i = seepage loss in terms of volume

$$V_i = WW_i LL_i - (WW_i + LL_i)\, hh_i^2 + 1.33\, hh_i^3$$

$$V_{i-1} = WW_{i-1}.LL_{i-1}\ hh_{i-1} - (WW_{i-1} + LL_{i-1}).(h\,h_{i-1})^2 + 1.33\,(hh_i)^3$$

$$WWi = W - 2F - 2\sum_{i=1}^{i-1}(s_i + d_i + 0 \cdot 7e_i - Rn_i)$$

$$LL_i = L - 2F - 2\sum_{i=1}^{i-1}(s_i + d_i + o.7e_i - Rn_i)$$

Where,

WW_i = width of water area in i^{th} week.

LL_i = length of water area in i^{th} week.

n = number of week when crop is planted

3000 = number of plants per hectare.

Now for each n starting from 29th week i.e. 3rd week of July, the above equation was solved to estimate minimum value of V.T. To check that sufficient water is available, following condition was checked.

$$ST_i = ST_{i-1} + [Q_i - R \cdot CA_i(E_i - P_i)\,3000 - LE_i - LS_i]/1000$$

Where ST_i = Volume of water in tank in i^{th} week

Q_i = runoff received in i^{th} week.

$$Q_i = \sum_{r=1}^{7}\left[\frac{(P_{ij} - 0.2s)^2}{P_{ij} + 0.8s}\right] CCR$$

S = 25400 / CN - 254

R = 0.8

For any week,

$$ST_i \geq R \cdot CA_i(E_i - P_i) \cdot 3000$$

A computer program has been made to solve this and optimum system has been determined.

Chapter-IV

RESULTS & DISCUSSION

RESULTS AND DISCUSSION

4.1 DISCHARGE THROUGH DIFFERENT DRIP SYSTEMS:

The discharge in drippers, micro tubes and inline drippers were measured with application of clean water with different filters. The discharge in lph with different drip system are shown in Table – 4.1.

Table-4.1 Discharge of different emitters (lph) with different filters

Discharge (lph)	Screen filter	Coconut coir	Jute	Mesh	Mesh with coir	Mesh with Jute
Microtube	7.54	7.11	7.67	7.67	7.2	7.7
Dripper	2.83	2.53	3.5	2.75	2.6	2.7
Inline dripper	0.70	0.675	0.8	0.91	0.66	0.7

The discharge through different filters have been shown in graphical form in fig.4.1. The discharge of micro tube is highest in mesh with jute filter (7.7 lph) and is lowest in coir filter (7.11 lph). The dripper discharge is highest in jute filter (3.5 lph) and lowest in coconut coir (2.53 lph). The inline dripper discharge is highest (0.91 lph) in mesh filter and lowest in coir filter (0.675 lph).

So considering the discharge the mesh with jute filter is a better one.

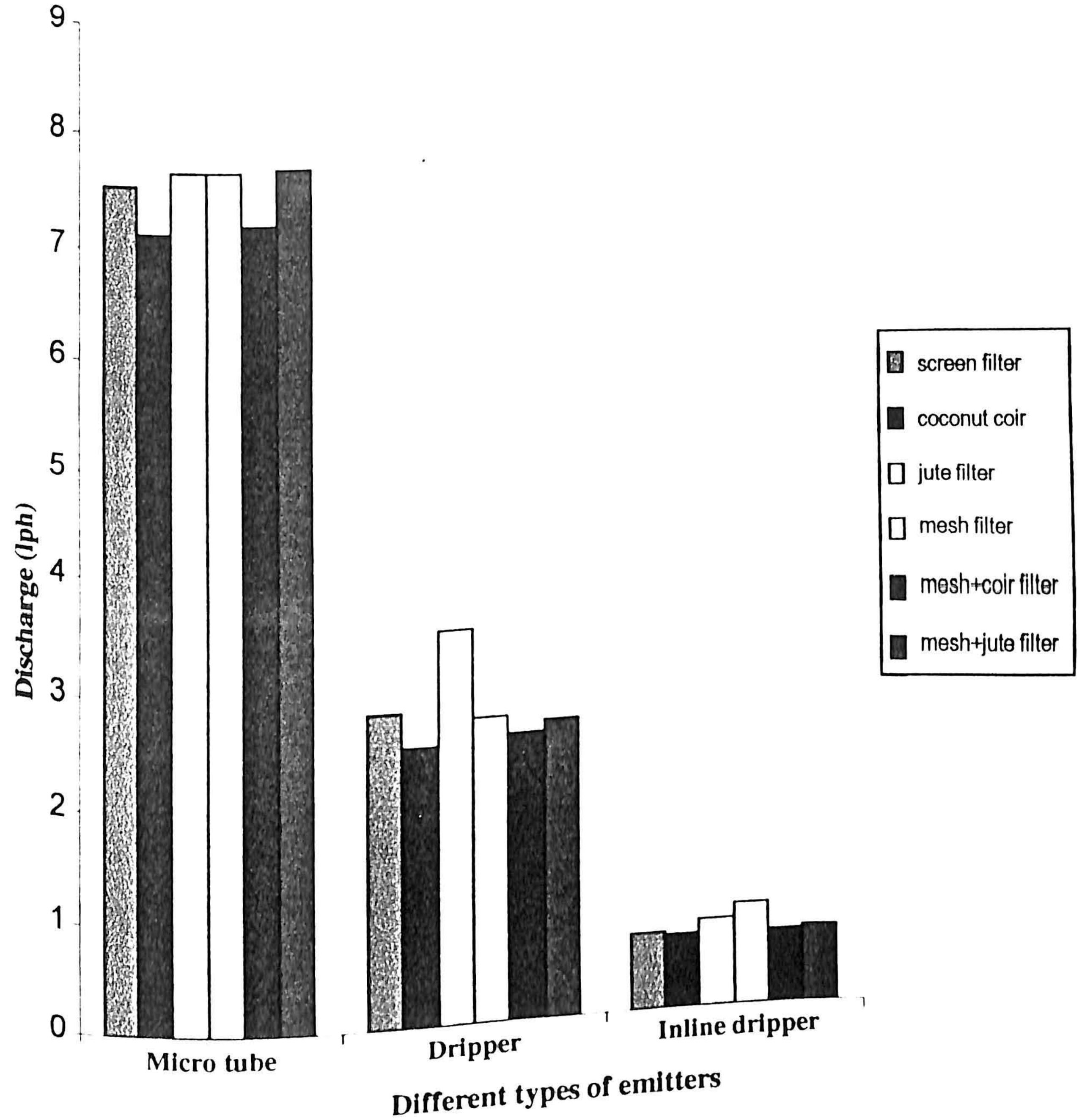


Fig. 4.1 Discharge of different emitters (lph) with different filters

4.2 HEAD LOSS IN DIFFERENT FILTERS :

Head loss in different filters were measured with different turbid water when the discharge through the later is (2.66lit/min). Clean water, 30ppm turbid water and 50ppm turbid water. This head loss values in cm of water are shown in Table-4.2.

Table-4.2 Head loss in different filters

	Screen filter		Coconut coir filter		Jute filter		Mesh filter		Mesh with coir filter		Mesh with jute filter	
	0min	15min	0min	15min	0min	15min	0min	15min	0min	15min	0 min	15 min
Clean water	17.5	19.0	1.0	1.2	21.5	22.0	0.5	0.7	1.6	1.9	8.5	10.0
30ppm	54.0	Choked	1.2	1.2	34.0	36.0	0.5	0.6	0.1	0.2	9.5	10.5
50ppm	69.0	Choked	1.4	1.7	52.0	53.0	0.9	1.0	1.7	1.9	10.0	10.5

This has been shown in graphical form in fig-4.2. Maximum head loss was observed in screen filter and jute filter. This was followed by mesh with jute filter. Lower head loss was observed in coir filter, mesh filter and mesh with coir filter. Lower head loss in coir filter can be attributed to lesser compaction in comparison to jute filter. Among water of different turbidity, maximum head loss was observed in 50ppm turbid water followed by 30 ppm turbid water and then clean water. It is evident that, when turbid water was used some of the pore spaces are choked. It affects the freeness with which the water moves through the filter. So it causes more head loss. The head loss in all the filters have been more after 15 min than at the beginning. After the filter runs for 15 minutes the pore spaces are slightly choked show the head loss.

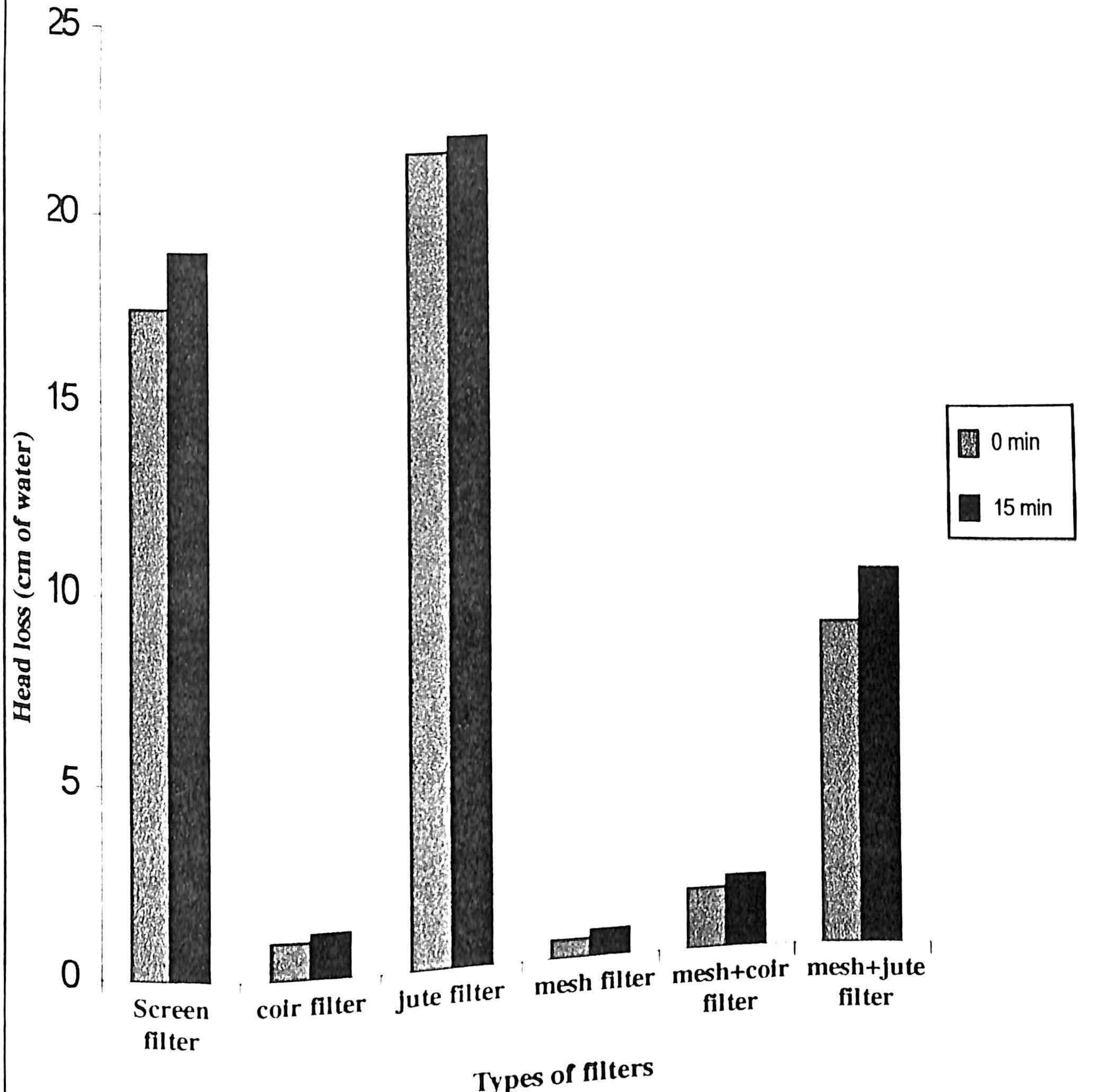


Fig. 4.2 Head loss in different filters

4.3. FILTRATION EFFICIENCY OF DIFFERENT FILTERS :

Filtration efficiency of different filters were measured by measuring the turbidity of inlet and outlet water. The experiment was conducted for 30 ppm turbid water and 50 ppm turbid water. The filtration efficiency of different filters are shown in Table-4.3.

Table-4.3 Filtration efficiency of different filters in percentage (%).

	Screen filter	Coir filter	Jute filter	Mesh filter	Mesh with coir filter	Mesh with jute filter
30 ppm	45.07	25.29	41.87	43.78	49.55	50.69
50 ppm	42.52	38.75	31.25	41.87	38.14	49.0

This has also been shown in a graphical form in fig-4.3. Maximum filtration efficiency 50.69% in case of 30ppm turbid water and 49% in 50ppm turbid water has been observed in mesh with jute filter. This filter is followed by mesh with coir filter, screen filter, mesh filter, jute filter and coir filter. So mesh with jute filter can be made a suitable replacement for screen filter as this involves less cost and has higher efficiency.

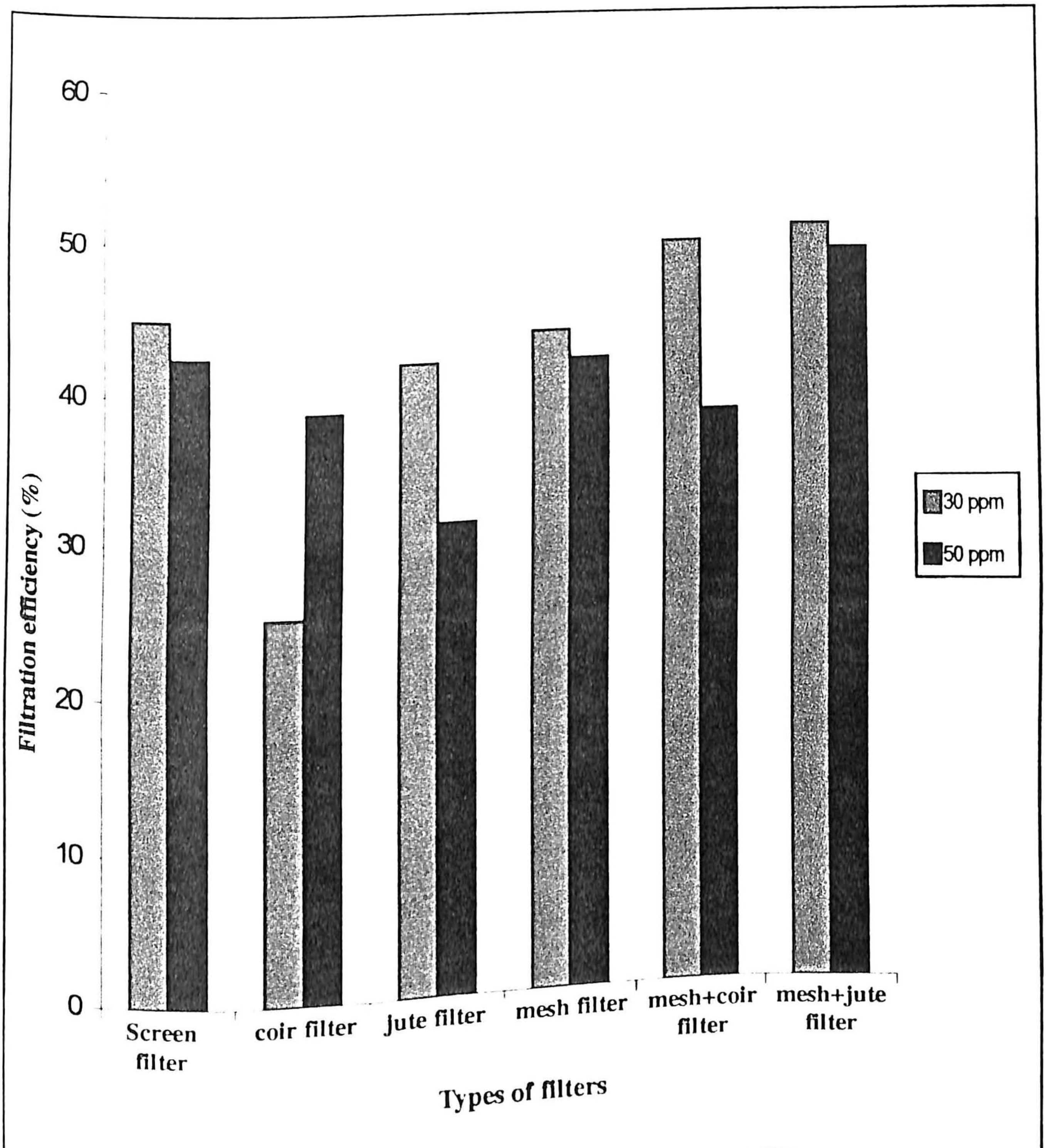


Fig. 4·3 Filtration efficiency of different filters

4.4. UNIFORMITY COEFFICIENT (UC) OF DIFFERENT DRIP IRRIGATION SYSTEMS WITH DIFFERENT FILTERS :

The uniformity coefficient of different drip irrigation systems were measured with clean water with different filters. The UC values are shown in Table-4.4

Table-4.4 Uniformity coefficient of different drip irrigation systems with different filters

	Screen filter	Coconut coir filter	Jute filter	Mesh filter	Mesh with coir filter	Mesh with jute filter
Microtube	94.8	83.73	92.56	95.21	94.09	92.69
Dripper	65.9	57.33	89.38	86.74	79.0	93.96
Inline dripper	93.61	93.33	93.33	97.1	93.93	97.1

Uniformity coefficient has also been shown in a graphical form in fig-4.4. Better U.C. have been observed in microtube and inline dripper. The UC in both the systems is more than 90% for all the filters. In comparison to these values the UC of drippers are less. As the discharge in micro tubes are more they can be preferred over inline drippers in such circumstances.

4.5 THE SELECTION OF PROPER FILTER :

The filters made by coconut coir, jute fibres, nylon mesh, nylon mesh with coir and nylon mesh with jute were found to have low cost as compared to screen filter. Cost of filters are Rs.425/-, Rs.450/-, Rs.425/-, Rs. 450/- and Rs.475/- respectively and screen filter having cost Rs.2000/-. Hence these low cost filters will be more beneficial to small and marginal farmers.

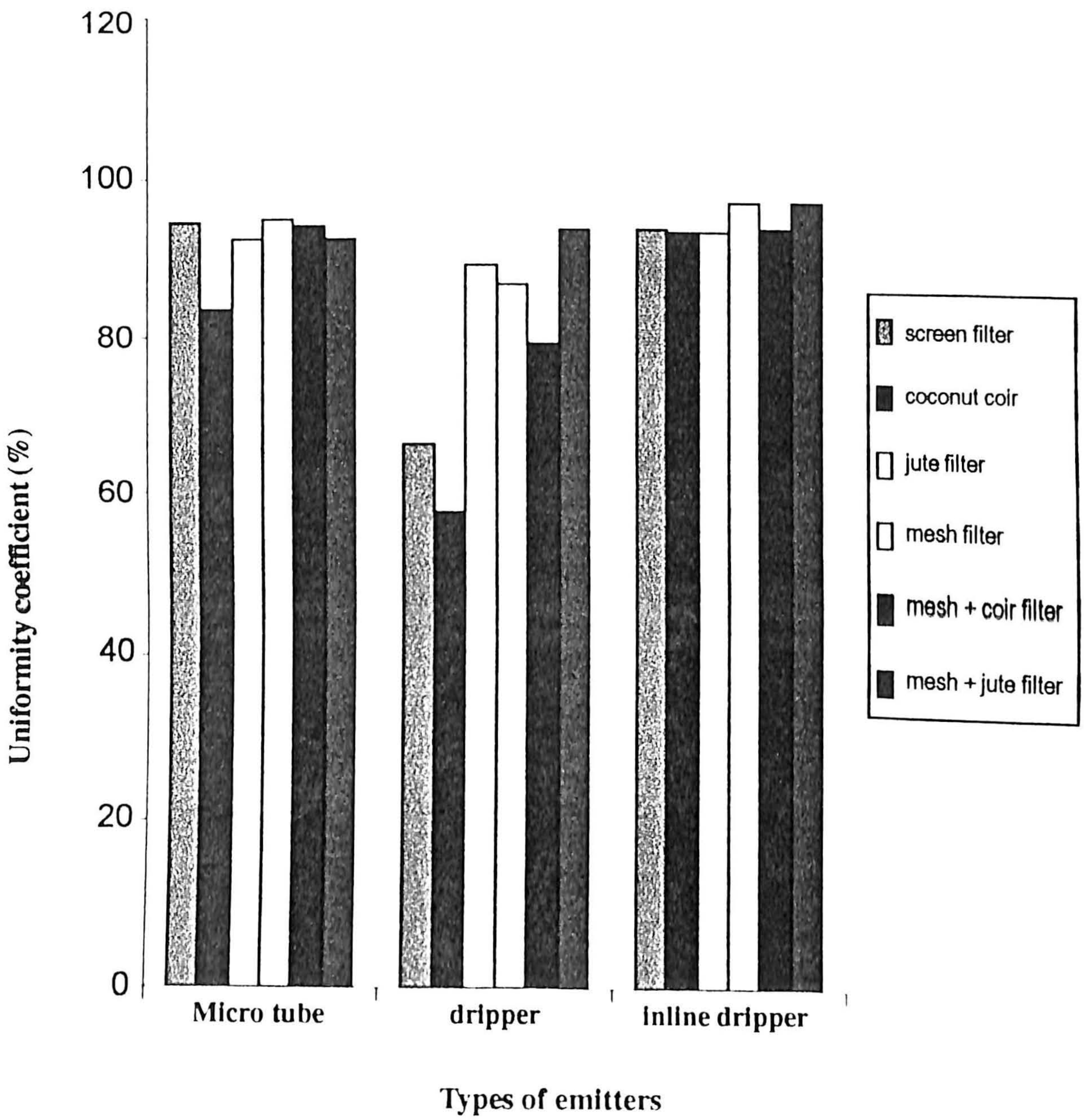


Fig. 4.4 Uniformity coefficient of different drip irrigation systems with different filters

While selecting the proper filter care has to be taken regarding their workability along with the cost. Mesh with jute filter was found to be best as its discharge, head loss, filtration efficiency and uniformity coefficient are 7.7 lit / hr., 9.75 cm of water, 50% and 95% respectively.

4.6 EFFECT OF PLANTING DATE ON IRRIGATION REQUIREMENT AND POND SIZE OF BANANA CROP :

According to the computer programme the total irrigation required (m^3/week) and total size of pond in (m^3) was found out. These are shown in Table 4.5.

Table 4.5 Irrigation requirement (m^3) and size of pond (m^3) in different meteorological weeks of a year for banana crop.

No. of weeks	Total irrigation required (m^3)	Pond size (m^3)
28	6683.8701	8539.8701
30	5558.753	7624.753
32	5058.273	7082.273
34	4447.442	6429.442
36	4188.93	6128.93
37	3946.443	5949.443

The same has also been shown in fig. (4.5). it shows the effect of change in planting date on size of pond and irrigation water requirement. It is evident that the amount of water required, as well as pond size decreases with delay in planting. This happens because the peak canopy area time coincides with the rainy season when no irrigation is required. The size and irrigation requirement will further decline if planting is done in October. However planting of samplings when there is no rain is risky as microclimate is hard and dry. In view of it the planting should be done around 37th meteorological week to get maximum benefit of rainfall and least losses. Based on this the following parameters of the Water Harvesting System for drip irrigated banana has been worked out.

Table 4.6 Details of the optimum system for banana crop.

Time of planting	37th week
Size of pond	5949.443 m^3 ≈ 6000 m^3
Amount of irrigation	3946.443 m^3 ≈ 4000 m^3
Catchment, command area ratio	≥6.0

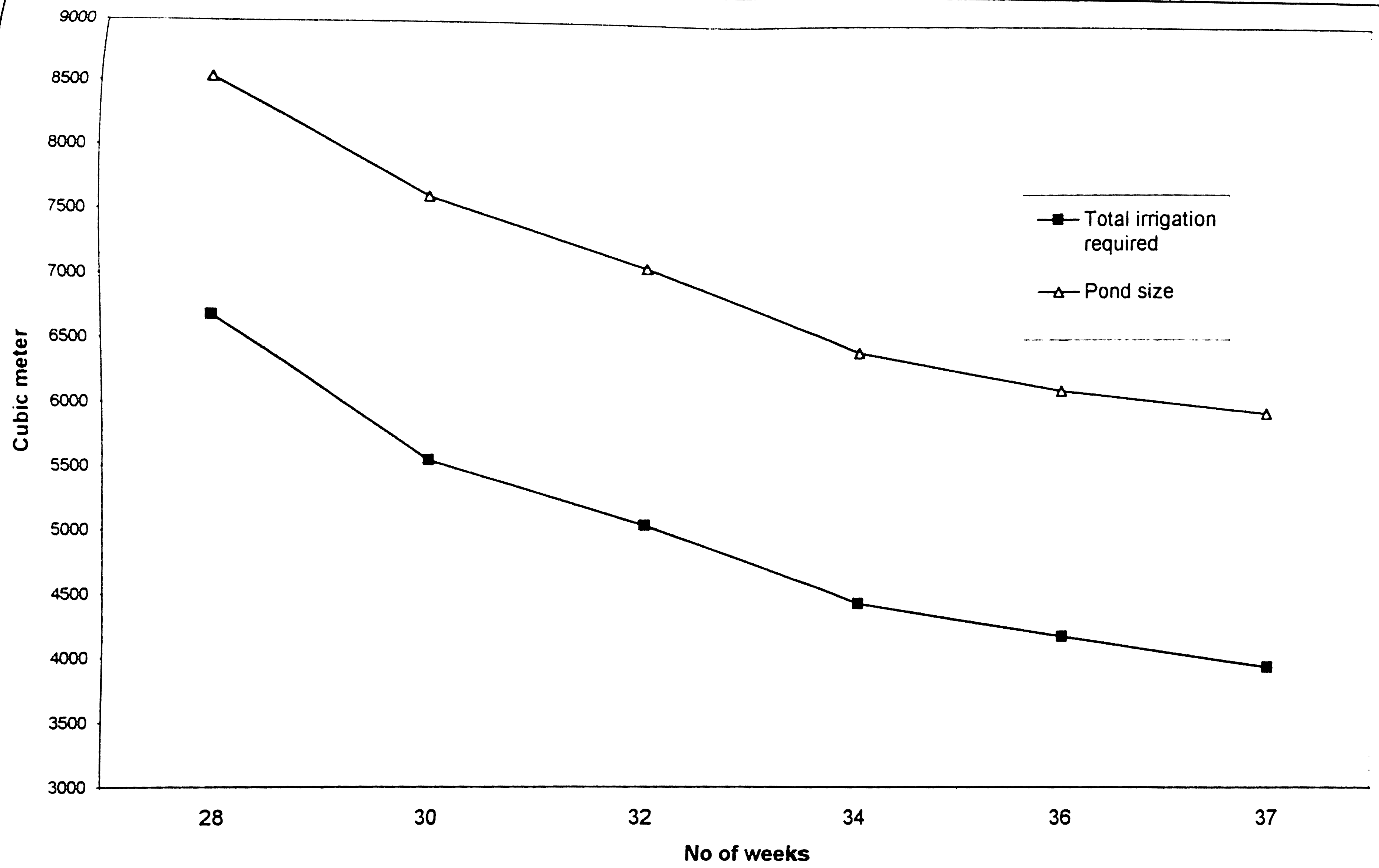


Fig.4.5 Effect of planting date on irrigation requirement and pond size

Chapter-V

SUMMARY & CONCLUSION

SUMMARY AND CONCLUSTION

To reduce the cost and to increase the filtration efficiency a low cost filter was fabricated. A 140mm dia PVC pipe of 45cm length was used as the outer cover of the filter and a 50mm dia was used as a base pipe for the filter. This was tested at five different arrangements i.e. as five different filters. They are

1. Coconut coir filter
2. Jute filter
3. Mesh filter
4. Mesh with coir filter
5. Mesh with jute filter

They were compared with a standard screen filter. To compare the performance of different filters an experimental set up was established. To allow the entry of water into the filters, a PVC pipe of 165mm dia was put vertically with the bottom closed. Water entered into the 165 mm dia. pipe through the top and constant head in the pipe was maintained by the arrangement of a by pass at the top. It ensured a constant water head in the filter. The filtration efficiency (FE) of all the filters were calculated by measuring the turbidity of inflow and outflow water. The mesh with jute filter was found to have maximum filtration efficiency. The F.E. of the above filter was 50.69% and 49.0% for 30 ppm and 50 ppm turbid water respectively.

Different type of drip irrigation systems were evaluated by using the above filters. They are online dripper, micro tubes and micro sprinklers. The micro sprinkler could not be operated as the available head was very less. The discharge of different drip irrigation systems were compared. The maximum discharge was observed in 1.2mm dia and 25cm long micro tubes. This was followed by drippers and inline drippers respectively.

The head loss in different filters with clean water, 30ppm & 50ppm turbid water were measured for different filters by using manometers. Maximum held loss was observed in 50 ppm turbid water followed by 30 ppm turbid water and then clean water. The head loss increased with duration of filtration. The turbid water choked the pore spaces in the filter and there by caused more head loss. Maximum head loss was observed in screen filter and jute filter.

The Uniformity coefficient (U.C.) of different drip irrigation systems were measured. The micro tubes and Inline drippers gave better U.C. than online drippers. Considering the discharge and U.C. The micro tubes were considered a better micro irrigation system under the present set-up.

A mathematical model for designing Water harvesting system for drip irrigated banana or chard was developed. The model showed that the planting should be done in the month of July. The size of tank for 1ha of banana should be about $6000m^3$ and the catchment :Command area ratio should be 6.0. The Pond can be used for fisheries and duckeries.

Chapter-VI

SUGGESTIONS FOR FUTURE WORK

SUGGESTIONS FOR FUTURE WORK

- Further work on filters for reducing turbidity of the harvested rain water is needed.
- Hydraulics of gravity fed drip irrigation should be studied in detail.
- Intensive study on intercropping in drip irrigated horticultural crops is needed.
- Intensive study on estimation of irrigation schedule of other crops are required.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alam Anwar and Kumar Ashwani, 2001. Micro Irrigation System Past, Present and Future. Microirrigation. Central Board of Irrigation and Power, pp. 1-15.

Anonymous. 1990. Training Programme on Sprinkler and Drip Irrigation Systems, Centre for Water Resources, College of Engineering, Anna University, Madras, July 16-26.

Bhensaniya R.V. and Parikh N.M 2001, Reclamation of Clogged Trickle Emitters through Chemical Treatments. Microirrigtion, Central Board of Irrigation and Power. pp. 562-568.

Bhattnagar P.R., and Srivastava R.C., 2001. Star Layout of Microtube Emitters- A New Drip Irrigation system for Hilly terraces, National Seminar on Water and Land Management including CAD for Socio economic upliftment of North Eastern region, Tezpur, Assam., pp. 39-43.

Bucks, D.A., F.S. Nakayama, and A.W. Warrick. 1987. Principles, Practices and Potentialities of Trickle (Drip) Irrigation. Advances of Irrigation Vol.1, 219-302

Buck & , D.A. *et al.*, 1979. Trickle Irrigation Water Quality and Preventive Maintenance. Agricultural Water Management 2: 149-162.

Chemmens, A.J. 1987. A Statistical Analysis of Trickle Irrigation Uniformity, Transactions of ASCE, 30(1), 169-173.

Dash Bijaya Kumar, 1989. Studies on Water Front Movement Under Drip System of Irrigation. Unpublished M. Tech Thesis, O.U.A.T., Bhubaneswar, Orissa

Dash, Nutan Kumar, 1998., Drip Irrigation Technology: Selection of Filters with reference to Orchard plants, Proceedings of the National Seminar on Micro-irrigation Research in India: Status and Prospective for the 21st Century WTCER, Bhubaneswar, Orissa, July: 27-28, 79-83.

Davis, S. (1975). Drip irrigation in "Sprinkler Irrigation" C.H. Pair, W.H. Hinz., C. Reid, and K.R. Frost. pp 508-528.

Dhal G.C, 1999. Comparative study of Drip Irrigation over conventional method of Irrigation in Tomato. Unpublished M. Tech Thesis, O.U.A.T., Bhubaneswar.

DWMR (1994) Annual Report, Directorate of Water Management Research, Rahuri.

Ghaemi. A.Ali 2001, Clogged Emitters and Hydraulics Characteristics in Micro-irrigation Lateral laid on Flat and Sloped Terrain, Micro Irrigation, Central Board of Irrigation and Power, pp. 88-89.

INCID. New Delhi 1994. Drip Irrigation in India, status report, Indian National Committee on Irrigation and Drainage, New Delhi.

Jaiswal. A.P., Aware V.V. and Powar. A.G. 2001, Field Evaluation of Hydraulic Performance of Drip Irrigation System, Micro irrigation, Central Board of Irrigation and Power, pp. 129-133.

Jain, R.B., 2001, Development of Micro Irrigation in India, Micro Irrigation, Central Board of Irrigation and Power, pp. 118-124.

Jackson. R.C., and Kay. M.G., (1987). Use of Pulse Irrigation for Reducing Clogging Problems in Trickle Emitters; Jr. of Agricultural Engineering Research. Vol. 37. pp. 223-227.

Katyal. J.C. and Hegde B.R. 1994. Rain Water Management for Sustaining Productivity of Indian Dry Lands. 8th ISCO Conference, pp. 287-296.

Michael. A.M. 1997. Irrigation Theory and Practice, Vikas Publishing House Limited. New Delhi.

Mohapatra. I.C., 1997. Strategy for productivity with available technology in handicapped ecologies including drought prone areas of Orissa. Proc. Workshop on Prevention of drought in Orissa, Bhubaneswar 1-7.

Nakayama, F.S. and Bucks D.A., 1981. Emitter Clogging Effects in Trickle Irrigation Uniformity. Transaction; ASAE 24:77.

Nakayama. F.S., Bucks, D.A. and Clemmens. A.J. 1979. Assessing Trickle Emitter Application Uniformity. Transaction of the A.S.A.E., pp. 816-821

Polak Paul, Nanes Bob and Adhikari, Deepak. 1997, A Low Cost Drip Irrigation System for Small Farmers in Developing Countries, Journal of the American Water Resources Association Vol. 33, pp. 119-124.

Patil, R.G. 2001. Water filtration for Micro Irrigation System, Micro Irrigation, Central Board of Irrigation and Power, pp. 574-580.

Pattnaik Saroj Kumar. 2000. Response of Banana to Drip Irrigation with Mulching Under Different Irrigation Regimes, Unpublished M. Tech Thesis, O.U.A.T, Bhubaneswar, Orissa.

Ravina, I. et.al., 1992. Control of Emitter Clogging in Drip Irrigation with Reclaimed Waste Water. Irrigation Science 13(3) : 129-39

Srivastava. R.C. and Bhatnagar. P.R. 1998. Design of Gravity- fed Drip Irrigation System. Progress in Micro Irrigation and Development in India, WTCER. pp. 84-95.

Srivastava. R.C. and Batnagar V.K., Bhatnagar. P.R. 1994. Rainwater Harvesting and Utilization for Sustainability of Hill Agriculture in U.P. Hills. 8^{th} ISCO Conference. New Delhi. pp. 354-366.

Srivastava. R.C., *et al.*, 1988a.Water Resource Development in the Hills-potential and Prospects. Wasteland News, III(3) : 33-35.

Srivastava, R.C. 1983, Providing Irrigation in Hilly, a Right Approach. Indian J. Soil Cons. 11 (2&3) 31-38.

Srivastava. R.C. (1988). LDPE Film Lined Tanks. Technical Bulletin, 2188, VPKAS. Almora (UP).

Srivastava. R.C. 1996 a Design of runoff Recycling Irrigation System for Rice Cultivation J. Irrigation and Drainage Engg. (ASCE). 122(6) 331-335.

Srivastava. R.C. 1996 b. A Methodology for Optimizing Design of Integrated Tank Irrigation System. J. of Water Resource Planing and Management (ASCE). 122 (6) 394-402.

Sahu. S.K. and Swain D; 1998. Principle for Estimation of Water and Power Requirement of Installation of Drip Irrigation System. Proceedings of the National Seminar on Micro Irrigation Research in India: Status and Perspective for 21^{st} Century. WTCER. Bhubaneswar, Orissa, July: 27-28, pp. 66-77.

Shoji. K. (1977) Drip Irrigation. Sci. Am. 237 (5). 62-68.

Singh Rajvir, Kale M.U. & Chandra Avdesh, 2001, Performance Evaluation of Microjets, Micro Irrigation, Central Board of Irrigation and Power, pp. 155-162.

Sanij. Hossein Dehghani, Torabi, Manochehr, Mirlatifi Majid, 2001. Effect of Water Quality and Irrigation Management on Emitter Clogging in South East of Iran, Micro Irrigation: Central Board of Irrigation and Power, pp. 537-545.

Suryawanshi S.K. and Panda R.K., 1993. Performance Study of Low Cost Fibre Materials for Drip Irrigation Filter, Irrigation and Power, April; pp. 33-40.

Srivastava. R.C. and Panda. R.K. 1998. Potential and Prospects of Runoff Recycling in Plateau Region of Eastern India, Indian Journal of Soil Conservation., 26(2): 104-112.

Srivastava, R.C. Singandhupe. R.B. Mohanty, R.K. and Verma. H.N. 2001. Water Resource Development Through Rainwater Harvesting and its Management by Multiple use of Water, Bhubaneswar, Orissa.

Srivastava. R.C. Singandhupe, R.B. Mohanty. S and Behera M.S. 2000-2001. Performance Evaluation of Drip Irrigation System for Orchard Crops, Annual Report, WTCER, Bhubaneswar, Orissa, pp. 110-113.

Shanti. R., Padmakumari, and Raman Sundar, 1998. Emitter Clogging Causes and Control: A Case Study, Proceedings of the National Seminar on Micro Irrigation Research in India: Status and Perspective for the 21st Century, WTCER, Bhubaneswar, Orissa, July: 27-28, pp. 73-78.

Sivanappan, R.K.. 1998. Status and Perspective of Micro Irrigation Research in India: Proceedings of the National Seminar on Micro Irrigation Research in India: Status and Perspectives for 21st Century, WTCER, Bhubaneswar, Orissa, July: 27-28, pp. 17-29.

Srivastava. R.C. 2001. Rainwater Harvesting in Plateau Region of Eastern India, Technique and Design. WTCER.

Srivastava. R.C. 2001. Methodology for Designing of Water Harvesting System for High Rainfall Areas. Agricultural Water Management, Vol. 47. Pp. 37-53.

Swain. S., 1998. Micro Irrigation System for Small and Marginal Farmers, Proceedings of the National Seminar on Micro Irrigation Research in India; Status and Perspectives for the 21st Century, WTCER, Bhubaneswar, Orissa, July 27-28, pp. 50-54

Singh. S.D. and Singh. P. (1978). Value of Drip Irrigation Compared with Conventional. Irrigation for Vegetable Production in a Hot Arid Climate. Agron. J. 70 : 945-947.

Sanij Hossein Dehghani. Torabi Monochehr & Mirlatifi Majid, 2001, Effect of Water Quality and Irrigation Management on Emitter Clogging in South-East of Iran. Micro Irrigation. Central Board of Irrigation and Power, pp. 537-545

Srivastava. R.C. and Upadhaya. A. 1998. Study on Feasibility of Drip Irrigation in Shallow Ground Water Zones of Eastern India, Agricultural Water Management. Vol. 36. pp.71-83.

Srivastava. R.C., Verma. H.C., Mohanty. S and Pattnaik. S. 2001. Investment Decision Model for Drip Irrigation system.

Tiwari, K.N., N. Kannan and P.K. Mal 1998. Enhancing Productivity of Horticultural Crops Through Drip Irrigation. Proceedings of the National Seminar on Micro-Irrigation Research in India. Status and Perspectives for the 21st Century, WTCER, Bhubaneswar, Orissa, July : 27-28; 44-49.

Wu, P., C.A. Sarauwatari, and H.M. Gitlin. 1982. Design of Drip Irrigation Lateral Length on Uniform slopes. Irrigation Science, 4, 117-135.

APPENDICES

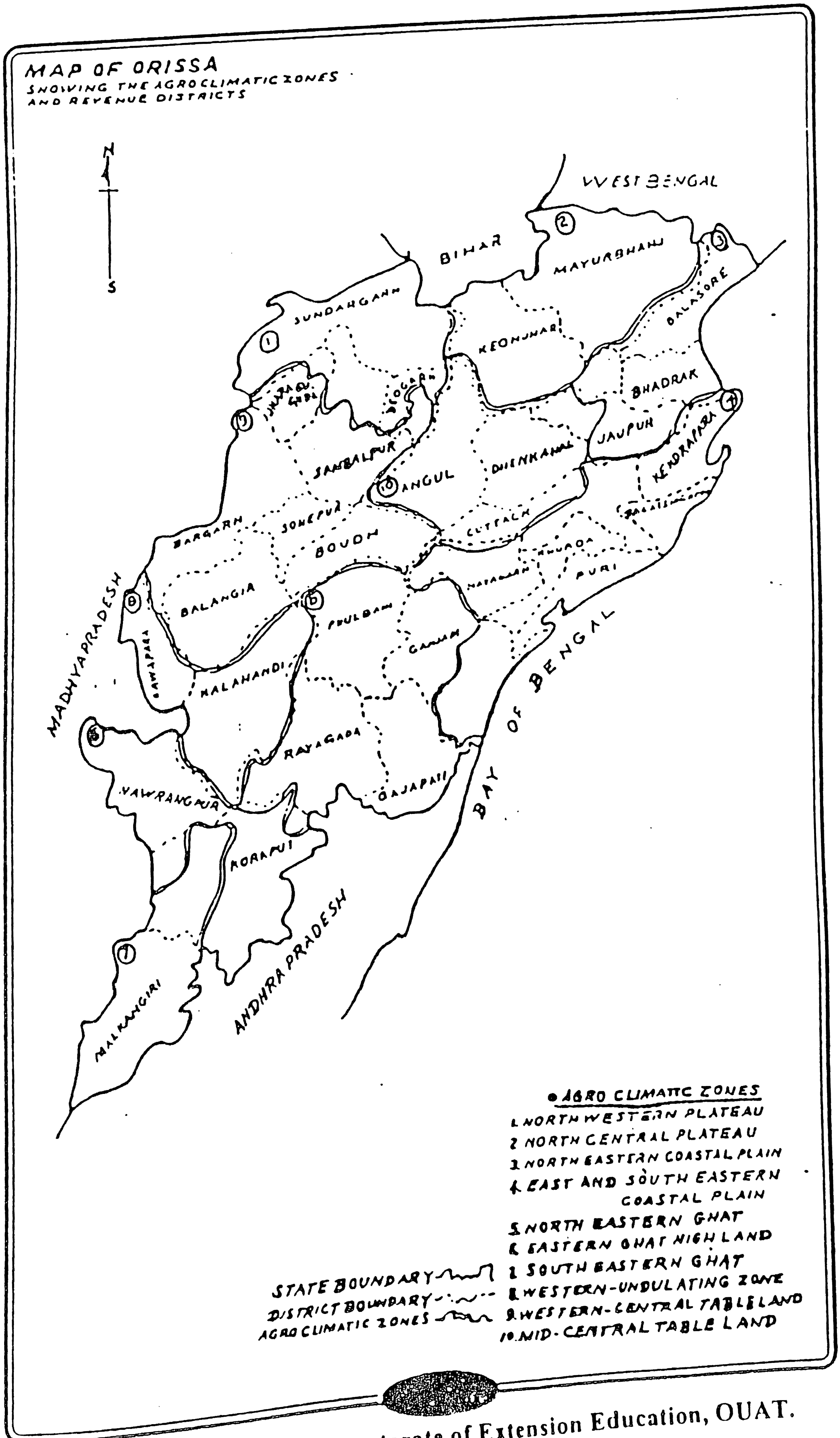
APENDIX-A

Agro-Climatic zones of Orissa

Sl. No.	Agro-climatic zone	Mean Annual rainfall (mm)	Agriculture districts	Area (in ha)
1.	Northern Western plateau	1600	Sundargarh, Panposh, Banaigarh, Kuchinda	1290.6
2.	North Central plateau	1534	Rairangpur, Baripada, Karanjia, Keonjhar, champua	1725.7
3.	North Eastern coastal plain	1568	Anandapur, Balasore, Bhadrak, Jajpur (except Sukinda block)	884.0
4.	East and South Eastern coastal plain	1577	Cuttack, Jagatsinghpur, Kendrapara, Banki, Puri, Berhampur, Chhatrapur	1685.0
5.	North-Eastern Ghat	1597	Khurda, Nayagarh, Aska, Parlakhemundi, Rayagada, Gunupur, Phulbani, Boudh.	2305.0
6.	Eastern Ghat highland	1521.8	Koraput, Nawarangpur (Except Dabugaon area)	955.3
7.	South East Ghat	1710.4	Jeypore, Malkangiri	659.0
8.	Western Undulating	1352.3	Bhawanipatna, Dharamgarh, Padampur, Kharia, Dabugaon area of Nawaranpur	1258.0
9.	Western Central Table land	1614	Sambalpur, Bargarh, Bolangir, Sonepur	1719.0
10.	Mid Central Table land	1470	Dhenkanal, Angul, Kamakhyanagar, Banki, Athagarh, Sukinda block of Jajpur Agril. District.	1364.2

Source : Das, R.N., 1997, Directorate of Extension Education, O.U.A.T.

APPENDIX –A



Source : Das, R. N., 1997, Directorate of Extension Education, OUAT.

APENDIX-B

Area covered under drip irrigation in India

State	Area (ha)	State	Area (ha)
Andhra Pradesh	31,600	Maharashtra	1,23,000
Assam	200	Orissa	2,800
Gujarat	8,000	Punjab	1,500
Haryana	1,900	Rajasthan	30,300
Karnataka	40,000	Tamil Nadu	34,000
Kerala	6,000	Uttar Pradesh	2,000
Madhya Pradesh	3,000	West Bengal	200
		Others	2,000
		Total	2,59,500

SOURCE : Microirrigation : Eds. Singh H.P., S.P. Kaushish, Ashwani Kumar, T.S.Murthy, Jose C. Samuel-2001.

APENDIX-C

Measurement of uniformity coefficient using screen filter

Micro tubes		Drippers		Inline drippers	
Discharge (ml/min) (x)	**Deviation from mean (d)**	**Discharge (ml/min) (x)**	**Deviation from mean (d)**	**Discharge (ml/min) (x)**	**Deviation from mean (d)**
135	9.286	75	27.715	13	1.25
125	0.714	31	16.285	11	0.75
120	5.714	37	10.285	12	0.25
135	9.286	76	28.715	11	0.75
110	15.714	35	12.285		
125	0.714	40	7.285		
130	4.286	37	10.285		
Σ x= 880	Σd = 45.714	Σ x =331	Σd=112.855	Σx=47.0	Σd=3.0
$\bar{X}$ = 125.714		$\bar{X}$ =47.285		$\bar{X}$ = 11.75	
UC = 94.8%		UC = 65.9%		UC = 93.61%	

APENDIX-D

Measurement of uniformity coefficient using coconut coir filter

Micro tubes		Drippers		Inline drippers	
Discharge (ml/min) (x)	**Deviation from mean (d)**	**Discharge (ml/min) (x)**	**Deviation from mean (d)**	**Discharge (ml/min) (x)**	**Deviation from mean (d)**
130	11.429	22	20.28	12	0.75
135	16.429	72	29.72	11	0.25
135	16.429	33	9.28	12	0.75
155	36.429	65	22.72	10	1.25
130	11.429	53	10.72		
130	11.429	26	16.28		
150	31.429	25	17.28		
Σ x= 830	Σ d =135	Σ x =296	Σd = 126.28	Σ x =45	Σ d =3
$\bar{X}$= 118.751		$\bar{X}$ = 42.28		$\bar{X}$ = 11.25	
UC = 83.73%		UC = 57.33%		UC = 93.33%	

APPENDIX-E

Measurement of uniformity coefficient using Jute filter

Micro tubes		Drippers		Inline drippers	
Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)
105	18.571	53	5.428	11	0.25
130	6.428	50	8.428	12	0.75
125	1.428	54	4.428	12	0.75
125	1.428	60	1.571	10	1.25
140	16.428	65	6.571		
110	13.571	72	13.57		
130	6.428	55	3.428		
$\sum$ x= 895	$\sum$ d =64.282	$\sum$ x =409	$\sum$d = 43.424	$\sum$ x =45	$\sum$ d =3
$\bar{X}$ = 127.857		$\bar{X}$ = 58.42		$\bar{X}$ = 11.25	
UC = 92.56%		UC= 89.38%		UC= 93.33%	

APPENDIX-F

Measurement of uniformity coefficient using mesh filter

Micro tubes		Drippers		Inline drippers	
Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)
125	2.857	61	15.142	15	0.33
130	2.142	44	1.85	16	0.666
135	7.142	33	12.85	15	0.33
125	2.857	52	6.15		
140	12.142	45	0.85		
115	12.857	44	1.85		
125	2.857	42	3.85		
$\sum$ x= 895	$\sum$ d =42.854	$\sum$ x =321	$\sum$d = 42.542	$\sum$ x =46	$\sum$ d =1.3266
$\bar{X}$ = 127.857		$\bar{X}$ = 45.85		$\bar{X}$ = 15.33	
UC = 95.21%		UC = 86.74%		UC = 97.11%	

APPENDIX-G

Measurement of uniformity coefficient `of mesh using coir filter

Micro tubes		Drippers		Inline drippers	
Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)
115	0.714	73	29.85	11	0
120	4.285	42	1.14	12	1
105	10.714	45	1.86	10	1
130	14.285	36	7.14		
115	0.7142	40	3.14		
120	4.285	35	8.14		
135	15	31	12.14		
$\sum x = 840$	$\sum d = 49.99$	$\sum x = 302$	$\sum d = 63.41$	$\sum x = 33$	$\sum d = 2$
$\bar{X} = 120$		$\bar{X} = 43.14$		$\bar{X} = 11$	
UC= 94.04%		UC= 79%		UC= 93.93%	

APPENDIX-H

Measurement of uniformity coefficient of mesh using jute filter

Micro tubes		Drippers		Inline drippers	
Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)	Discharge (ml/min) (x)	Deviation from mean (d)
125	3.571	43	2	15	0.333
150	21.429	44	1	16	0.666
125	3.571	43	2	15	0.33
125	3.571	46	1		
120	8.571	44	1		
140	11.429	53	8		
115	13.571	42	3		
$\sum x = 900$	$\sum d = 65.713$	$\sum x = 315$	$\sum d = 19$	$\sum x = 46$	$\sum d = 1.33$
$\bar{X} = 128.571$		$\bar{X} = 45$		$\bar{X} = 15.33$	
UC = 92.69%		UC = 93.96%		UC= 97.1%	